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Hon. Marcel Masse, Minister

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L'Hon. Marcel Masse, Ministre

Canada

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Final Report

WOOD-WASTE FUELLED INDIRECTLY-FIRED GAS TURBINE COGENERATION PLANT FOR SAWMILL APPLICATIONS
Phase II:
Site-Specific Preliminary Engineering and Financial Analysis

PREPARED FOR:

BIOENERGY DEVELOPMENT PROGRAM
Energy, Mines and Resources Canada
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PREPARED BY:

Canadian Resourcecon Ltd.
Suite 309 - 811 Beach Avenue
Vancouver, B.C.
V6Z 2B5

(604) 682-8691

R.L. Evans & Associates Ltd.

Bachrich Consulting Ltd.

SCIENTIFIC AUTHORITY:

J.M. Charron
Technology Branch
Energy, Mines and Resources Canada
460 O'Connor Street
Ottawa, Ont.
K1A 0E4

90-01356/

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ABSTRACT

The objective of this project is to develop a cost-effective system to generate electricity and dry kiln heat for sawmills, using an indirectly-fired gas turbine cycle. Sawmill residues are used as fuel to heat clean air which will power the turbine before exhausting through a heat exchanger in the lumber dry kiln. Based upon the generic design developed in Phase I of the project, a preliminary engineering and financial analysis for a specific demonstration site was undertaken in Phase II.

Sommaire

Le projet a pour but d'élaborer un système rentable qui permettra de produire de l'électricité et de la chaleur pour faire fonctionner un séchoir à bois au moyen d'un système comportant une turbine à gaz indirectement alimentée. Les résidus du bois sont d'abord brûlés dans une chambre à combustion classique. Les gaz chauds produits dans la chambre à combustion passent dans un échangeur de chaleur où de l'air propre est chauffé. Cet air fait ensuite tourner une turbine qui produit de l'électricité, puis il est acheminé directement aux séchoirs (voir le diagramme de la p. 2).

Au cours de la Phase II du projet, l'on a effectué une analyse préliminaire en vue du financement et de la conception d'un site de démonstration et ce, à partir des données générales établies lors de la Phase I.

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EXECUTIVE SUMMARY

Introduction

Although most sawmills generate more than enough wood waste to be potentially self-sufficient in both dry-kiln heat and electricity requirements, it is not generally economically viable to use conventional steam/electricity cogeneration systems at the sawmill scale of operation. The overall objective of this project, therefore, is to develop a cost-effective wood waste-fired power generation and dry kiln heating system for sawmill applications.

The system proposed and evaluated in this project is a wood waste-fuelled, indirectly-fired gas turbine cogeneration plant. Research, design and development of the system has been planned to take place in a number of phases. In Phase I of this project, completed in February 1987, a generic preliminary engineering design and financial evaluation were prepared for a cogeneration system of this type. On the basis of favourable results from the Phase I analysis and expressions of interest by sawmill industry officials, the study team sought and received approval and funding from the Bioenergy Development Program (Renewable Energy Branch of Energy, Mines and Resources Canada) to proceed with Phase II of the project. The overall objective of Phase II is to advance the generic design of Phase I by preparing a preliminary engineering design and financial analysis of the system at a specific demonstration site.

Demonstration Site Description

After reviewing the Phase I report, British Columbia Forest Products indicated that it was interested in having its sawmill at Boston Bar, B.C. considered as a potential demonstration site. This mill, located on the Fraser River about 190 kilometres by road east of Vancouver, cuts about 100 million board feet of lumber annually, of which 30 percent is currently kiln-dried using propane as a fuel. The company plans to increase the kiln-dried proportion of its output to at least 60 percent within a year, requiring the construction of a third kiln.

With the planned expansion in kiln-dried output, the company would increase its propane consumption considerably if it were to continue using this fuel. Given the high cost of propane to the mill ($8/GJ versus $3.50 for B.C. mills using natural gas), the company also plans to install a wood-fired burner to provide heat for the kilns. Its consideration as a demonstration site therefore appeared to be timely. Electricity to the mill is supplied from the B.C. Hydro grid at standard industrial rates ($0.0264/kWh, $6.01/kW monthly demand charge).

Cogeneration System Design

A number of alternative system configurations were identified and preliminary engineering designs prepared for each. Equipment suppliers were contacted to establish the availability and cost of system components. The following three options were considered:

Option 1: wood wastes are combusted in a wet cell type hot gas generator. Hot gases leaving the combustor are directed into a tubular recuperative air heater before going into a 600 kW (net output) turbine. Turbine exhaust and flue gas are then directed through an oil heater which provides heat input of 7,000 kW for the dry kilns.

Option 2: provides the same electrical and heat output as Option 1, but uses a down-fired suspension burner unit, together with an integral air heater heat exchanger which has both convective and radiant sections. The fuel for the suspension burner consists of clean sawdust which is first dried to a moisture content of approximately 10 percent. A hot oil kiln heating system is also employed in Option 2.

Option 3: represents a commercial-scale configuration with an electrical output of 1,800 kW, which is near the mill's average requirement, and sufficient heat output for the three dry kilns. The layout of the system is similar to that of Option 2, except that the

thermal oil kiln heating system is replaced with a system of air-to-air heat exchangers in the kilns.

After examining these three options, Options 2 and 3 were short-listed as options to be considered in the financial analysis and, ultimately, in a demonstration project. Option 1 is not a preferred option for two reasons: first the capital cost estimate is significantly greater than for Option 2; second, a major technical risk exists with respect to the design, fabrication and cost of the tubular recuperative air heater.

Financial Analysis

Projected capital and operating costs of Options 2 and 3 were balanced against savings in purchased fuel and electricity costs in a computerized financial feasibility model. This model calculated the after-tax internal rate of return on the two systems and examined the sensitivity of the rates of return to changes in a number of variables, including; base year energy prices, rates of energy price escalation, capital cost, debt/equity ratio, and project lifetime. Rates of return are calculated not only for the overall system, but also for the incremental cost of adding the electrical generation portion of the system to a wood-fired kiln drying system.

Option 2

The capital cost of Option 2 is estimated at about $3.3 million, while annual operating costs are estimated at about $200,000. With current propane and electricity prices at the Boston Bar site, this system would reduce purchased energy costs by more than $800,000 annually with the planned increase in kiln-dried lumber output.

While the overall system generates an attractive rate of return (36.5 percent in the Base Case), the rate of return on the incremental

investment required for electrical generation is very low without substantial capital grants (2.1 percent in the Base Case). The low return on the incremental electric generation can be traced directly to the 600 kW demonstration scale of the system. In order to make a demonstration project attractive to a commercial operator, a sizable grant is needed from government funding agencies and/or the capital cost needs to be reduced. Cooperative arrangements whereby a manufacturer could be persuaded to loan (or lease for a relatively short period of time) a suitable turbine generator would be one means of reducing the capital cost of a demonstration project.

Option 3

This option is intended to illustrate the potential of the cogeneration system at a commercial scale and under more favourable electricity price circumstances than exist at the Boston Bar site. In this case it is assumed that the system will operate 350 days per year at full output of 1800 kW, with the output valued at 5 cents per kWh. In the Base Case analysis of this option, natural gas priced at $4.50 per GJ is assumed as the kiln heating fuel. In effect, this case is representative of a northern Ontario location.

In the Base Case analysis of Option 3, the after-tax rates of return on the electric generating portion of the system (45 percent) and on the overall system (42 percent) are both very acceptable. A 25 percent increase in capital cost reduces the after-tax IRR to 34 percent for the electric generation portion of the system, a level that is still acceptable. Given the lower electric rates that prevail in B.C. and the present inability to sell surplus power, however, the return on the electric generation portion of the system for a Boston Bar location would fall to about 18 percent.

Conclusions and Recommendations

In the context of the system design, preliminary engineering, and budget prices developed, we believe that the indirect-fired cogeneration approach is technically and economically sound. One of the key technical problems, a workable combustor/air heater arrangement, appears to be successfully addressed by the combined unit upon which Options 2 and 3 are based.

The reduced scale of operation associated with the demonstration-scale Option 2 system and low electricity rates in British Columbia combine to provide an inadequate rate of return at the Boston Bar site without substantial outside support for a demonstration project. Still, given the technical risks, the 600 kW scale may be appropriate for a first project utilizing the indirect-fired approach proposed herein.

At a commercial scale of operation and with the higher electricity prices that exist outside of British Columbia (Option 3), the financial analysis indicates that the incremental investment in the electric generation portion of the system provides very attractive rates of return.

For these reasons, the study team believes that the results of Phase II are positive and recommends that Phase III of the project be proceeded with in order to identify an appropriate demonstration site and to organize a demonstration project. Such a site would be a sawmill with the following characteristics:

- relatively expensive energy;
- either a good load factor or a market for surplus power;
- institutional support (government or industry);
- a sawmill operator who is personally interested in the project.

The major objectives of Phase III are to:

- identify a short list of suitable sites and industrial participants;
- identify funding alternatives, both industry and government;
- evaluate a short list of sites;
- structure a demonstration project.

1.0 INTRODUCTION

1.1 Background

Although most sawmills generate more than enough wood waste to be self-sufficient in both dry-kiln heat and electricity requirements, it is not generally financially viable to use conventional steam/electricity cogeneration systems at the sawmill scale of operation. In Phase I of this project, completed in February, 1987, an engineering design and financial evaluation were prepared for an innovative type of cogeneration system - "A Wood-Waste Fuelled, Indirectly-Fired Gas Turbine Cogeneration Plant For Sawmill Applications".

In Phase I of this project, a number of alternative design concepts were reviewed before arriving at the indirectly-fired turbine concept selected for development. The general concept involves the use of an open Brayton-cycle gas turbine as the prime mover to generate electrical power, while process heat for the lumber dry-kiln is obtained by waste heat recovery from the turbine exhaust gas. Figure 1 presents a simple schematic of the system considered in Phase I.

During Phase I of this project, a generic design for a cogeneration system of this type was prepared for a typical sawmill producing 50 million board feet of lumber. The proposed system would have several major advantages over a conventional steam-based cogeneration system:

- reduced capital and maintenance costs;
- no requirement for full-time licenced operators;
- no need for condenser cooling water.

The Phase I analysis indicated that the indirectly-fired gas turbine system was both technically and financially feasible under a variety of conditions. On the basis of the favourable results from the Phase I analysis and strong expressions of interest by sawmill industry officials, the study team sought and received approval and funding from the Bioenergy Development Program (Renewable Energy Branch of Energy, Mines and Resources Canada) to proceed with Phase II of the project.

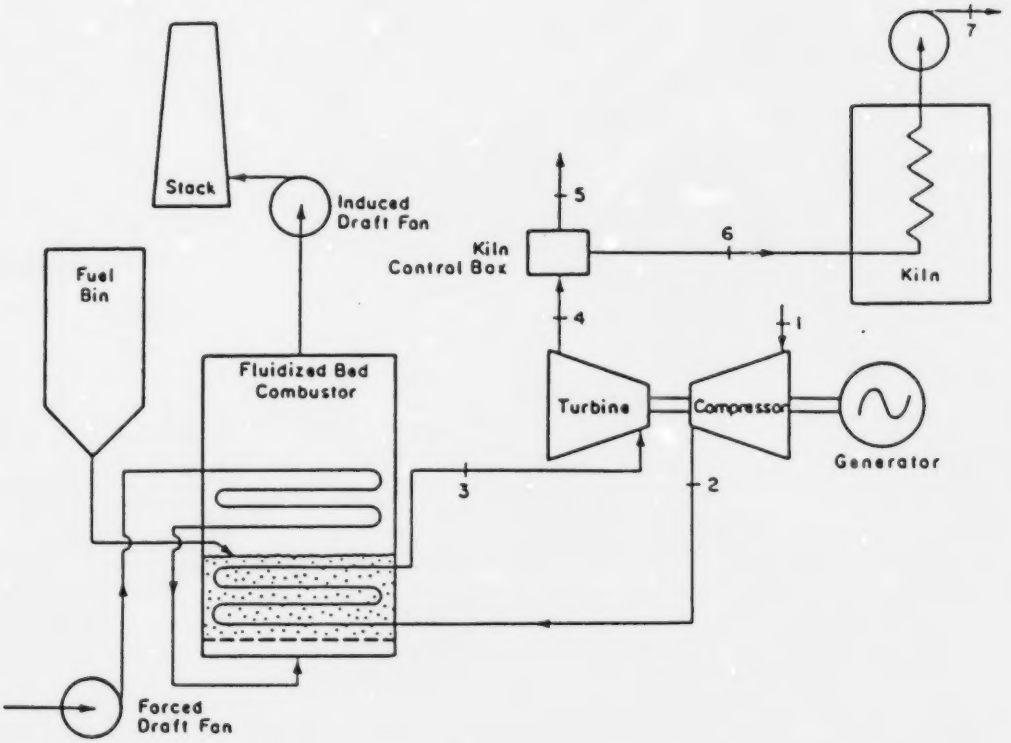


FIGURE 1: THE INDIRECTLY-FIRED GAS TURBINE COGENERATION SYSTEM

Note: This simplified schematic drawing represents the version of the cogeneration system considered in Phase I. During Phase II a number of variations on this system were explored, including different combustor/heat exchanger types and configurations, and the use of a hot oil system for kiln heating. See Drawings 87-50-002 to 87-50-008 in Appendix 2 for details.

1.2 Objectives of Phase II

The overall objective of Phase II of this project is to prepare a preliminary engineering design and financial analysis for a specific demonstration site to the stage where a participation agreement can be put together for a demonstration project using the system proposed herein. In order to meet this general objective, the project tasks were to:

(i) Find an industrial participant and a sawmill site for the demonstration project;

(ii) Establish energy and materials balances for the sawmill, along with operational characteristics.

(iii) Identify alternative configurations of the cogeneration system which would be appropriate to the capacity and operational needs of the sawmill;

(iv) Prepare preliminary engineering designs for the selected system configurations;

(v) Contact equipment suppliers to establish the availability and cost of system components; prepare a budget estimate for the complete cogeneration system;

(vi) Carry out a financial feasibility analysis of the selected cogeneration system design to determine its viability in the demonstration site.

(vii) Propose a participation agreement for a demonstration project at the industrial participant's sawmill site. Such an agreement would cover cost sharing of the capital cost of the cogeneration system, as well as any ongoing monitoring costs, between the industrial participant and government agencies.

1.3 Method

After reviewing the Phase I report, British Columbia Forest Products indicated that it was interested in having its sawmill at Boston Bar, B.C. considered as a demonstration site. This site was selected as the demonstration for a number of reasons, outlined in Section 2.

A meeting was held at the Boston Bar mill site to establish present and planned levels of kiln-dried lumber output and energy use, along with other operational characteristics of the sawmill relevent to the sizing and design of the cogeneration system.

A number of alternative system configurations were then identified and preliminary engineering designs prepared for each. Equipment suppliers were contacted to establish the availability and cost of system components.

Projected capital and operating costs of the system were balanced against savings in purchased fuel and electricity costs in a financial feasibility model. This model calculated the after-tax internal rate of return on the project and examined the sensitivity of the rate of return to changes in a number of variables including: rate of energy price escalation, capital cost, debt/equity ratio, and financing rate.

In Phase I, the financial feasibility was performed on the cogeneration system as a integrated system providing both electric energy and kiln heat. In Phase II, it became apparent that the more appropriate analysis is to calculate the financial feasibility of the electric energy portion of the system on an incremental basis relative to a system which would only produce heat for the kilns. The reason for this is that sawmills have a number of system options and equipment available for providing kiln heat from wood wastes. These systems produce excellent financial returns when compared to fossil fuel based kiln heating systems; hence, the relevent comparison is whether the incremental revenue from electric generation provides an acceptable return compared to the incremental capital cost associated with electric generation.

The one task which has not been completed in Phase II as anticipated is the development of a demonstration project for the Boston Bar sawmill. For a number of reasons discussed in Section 5.1; the Boston Bar sawmill is not an appropriate site for a demonstration project. Section 5.1 outlines the key parameters for a successful demonstration project and outlines a Phase III study to identify a site and organize a project.

2.0 DEMONSTRATION SITE DESCRIPTION

The Boston Bar sawmill of British Columbia Forest Products, located on the Fraser River 190 kilometres east of Vancouver by road, was selected as the demonstration site for Phase II of this project. This mill cuts about 100 million board feet of lumber annually, of which about 30 percent is currently kiln-dried using propane as a fuel. The mill operates on a 3-shift/day basis, 5 days per week. Dry kilns are charged 3 times per week, with an average drying time of about 28 hours. During the summer months, much of the lumber output is air-dried. The company plans to increase the kiln-dried proportion of its output to at least 60 percent within a year. In order to accomplish this, a third dry kiln will have to be constructed. Drawing 87-50-001 in Appendix B shows site plan for the Boston Bar sawmill.

This sawmill is not a typical British Columbia interior mill, as it cuts both coastal and interior species, with a wide variation in moisture contents. Spruce/pine account for about 34 percent of the cut, hemlock/balsam for 30 percent, douglas fir for 26 percent, and cedar for 10 percent. By-product wood chips are trucked to the Vancouver area, while sawdust, planer shavings, bark, and other wood waste are burned in a tepee burner. This burner does not comply with provincial air quality standards, so the company must install a cleaner burning combustion system by mid-1988. Estimated quantities and characteristics of wood waste available are shown in Table 2-1, along with energy use patterns of the mill.

Propane fuel for the dry kilns is currently delivered to the mill by tanker truck. With the planned expansion in kiln-dried output, the company would increase its propane consumption considerably if it were to continue using this fuel. Given the high cost of propane to the mill ($8/GJ versus $3.50/GJ for mills using natural gas), the company also plans to install a wood-fired burner to provide dry-kiln heat.

TABLE 2-1: MATERIALS AND ENERGY BALANCE FOR BOSTON BAR SAWMILL

Nominal Output: 100 Million fbm (236,000 m3)
@720 shifts/year
(surfaced lumber, 60 million fbm kiln-dried)

MATERIALS BALANCE	% log volume	m3 SWE
Finished lumber	37%	168,182
Pulp chips	40%	181,818
Sawdust	9%	40,909
Shavings	10%	45,455
Other (a)	4%	18,182
Total wood input (b)	100%	454,545
Bark	15%	68,182

WOOD WASTE AVAILABILITY AND CHARACTERISTICS

Component	m3 SWE	Oven-dry Density (kg/m3)	Oven-dry Weight (tonnes)	Higher Heating Value (GJ/ODT)	Actual Moisture Content (wet basis)
Sawdust	40,909	400	16,364	20	45%
Shavings	45,455	400	18,182	20	15%(c)
Bark	68,182	500	34,091	20	50%
Other	18,182	400	7,273	20	45%
Total	172,727		68,636		

ENERGY REQUIREMENTS				ENERGY PRICES:
Electricity:	Energy	160 kwh/mfbm	16,000 Mwh/Annum	@ 2.64 cts/kwh
	Demand	3200 kw Peak	2000 kw Avg	@ $6.01/kw/month
Kiln Fuel (d)		1.4 GJ/mfbm	84 TJ/Annum	@ $8/GJ

NOTES:

SWE - Solid Wood Equivalent

Nominal Output - is higher than the actual output of finished lumber, as it is based on the nominal, rather than actual, dimensions of the planed and kiln-dried lumber.

(a) Chip fines and solid wood residues.

(b) Based on Lumber Recovery Factor of 220 fbm/m3 of wood input.

(c) For the 60% of output that is kiln-dried; remaining 40% at 45% MC.

(d) Propane; actual quantity required may be less on average due to extensive air drying in summer months.

Electricity to the mill is supplied from the B.C. Hydro grid at standard industrial rates. Boston Bar is located at the end of a B.C. Hydro branch transmission line that reportedly is becoming capacity-critical. The mill has an average demand of about 2000 kW and a peak monthly demand of about 3200 kW. Electricity consumption in recent years has averaged between 150 and 160 kwh per thousand board feet of lumber output.

The Boston Bar mill is suitable as a demonstration site in several respects:

- its proximity to Vancouver would keep construction and monitoring costs to a minimum;
- it currently uses propane for kiln-drying, thereby providing a higher potential payback on the system than a mill using natural gas;
- unlike many other sawmills, it operates on a 3-shift/day basis, providing better capacity utilization for a generator;
- mill management was planning to convert to a wood-fuelled system for kiln-drying in any event; therefore its consideration as a demonstration site for the cogeneration system is timely.
- the B.C. Hydro transmission line which supplies the mill is becoming capacity-critical, as noted above, providing a more compelling reason for cogeneration at the mill.

3.0 SYSTEM DESIGN

3.1 Design Criteria

In Phase I of this project a generic design was developed for a cogeneration system based on an indirectly-fired gas turbine; the analysis was carried to the point where a preliminary design and cost estimate, and materials and energy balances were completed. The design objective of Phase II is to advance the generic design of Phase I by completing preliminary engineering on a specific site. The intention was that if the preliminary engineering results were positive, then a demonstration project would be organized for the site. The idea that Phase II should lead directly to a demonstration means the adoption of two design restrictions:

- o equipment selection should be restricted as much as possible to proven components quoted from established suppliers.

- o in order to minimize the technical and economic risks, the technology should be demonstrated with a relatively small turbine unit, while still properly testing the indirectly-fired concept and major equipment components.

The key equipment components in the system are the combustor/air heater heat exchanger configuration and the gas turbine. For an indirectly-fired system it is essential to have a turbine engine which has either been designed for a single external combustor, or for recuperated operation. Either of these designs makes it relatively straightforward to duct the compressor discharge air into the heat exchanger, and the heated air exiting from the heat exchanger back into the turbine. There are not many machines available in the required size range that meet these requirements, and are thus suitable for indirect firing.

The gas turbine chosen for this study was a Solar Saturn unit, with a nominal output of 1055kW when operating on distillate fuel; this output is considerably reduced at the lower turbine inlet temperatures achievable with indirect firing.

The Solar Saturn is one of the few gas turbines available in this size range with ducting designed for recuperated operation, making it suitable for indirect firing. The gas turbine is a single-shaft machine which also makes the problem of speed control easier if the electrical generator is arranged for parallel operation with the utility electrical grid.

The overall design conditions for the cogeneration system are shown in Table 3-1. The maximum reasonable turbine inlet temperature achievable with an indirectly-fired system is estimated to be about 760°C (1400°F), given the difficult materials problems associated with designing an all-metallic heat exchanger for this service. The turbine's net power output is therefore reduced to 600kW from the distillate-fuelled value of 1055kW, although this is sufficient to provide nearly one-third of the mill's average electrical requirements. The heat input required for each of the dry-kilns is estimated as 8 million Btu/hr during the peak heating period of the lumber drying cycle, or a total of 24 million Btu/hr when all 3 kilns are in operation. During most of the drying cycle the total kiln heat requirements would be considerably less than this, so that provision is made to by-pass flue gas and turbine exhaust air around the kiln heat exchanger during off-peak operation.

TABLE 3-1

COGENERATION SYSTEM DESIGN CONDITIONS

Turbine Air Mass Flow Rate	0.1 kg/s
Compressor Efficiency	80%
Turbine Efficiency	87%
Turbine Pressure Ratio	6.1
Turbine Inlet Temperature	760°C
Net Power Output	600 kW
Kiln Heat Input	7,000 kW

The emphasis on proven components resulted in a review of combustor/air heater alternatives other than the fluid bed combustor with in-bed tubes (Fluidyne Corporation of Minneopolis) used in Phase I. Two air heater concepts were investigated, resulting in two different equipment configurations and two budget estimates (Options 1 and 2).

Option 1 is based on the use of a tubular recuperative heater located in the exit flue gas stream from a wet fuel combustor, while Option 2 consists of a single cylindrical vessel incorporating a down-fired suspension burner unit along with an integral air heater heat exchanger which has both convection and radiant sections. A more detailed description of these combustor/air heater alternatives and their relative merits is provided in section 3.2

Thermal oil systems are a current standard in the kiln drying industry and a decision was made that thermal oil would be the transfer medium for heating the kilns. Initial calculations showed that humidity control could not be properly maintained if the turbine exhaust gas was used directly in the kiln.

Capital cost estimates are based on the consultants acting on behalf of the owners. That is, quotations were sought for the major equipment components and engineering estimates were developed for the remainder. In addition to the equipment quotations, an amount for engineering, project management and a contingency has been included in the budget estimates.

3.2 Systems Options

Three system options are presented. Option 1 and Option 2 are the two different combustor/air heater alternatives combined with the Solar Saturn turbine. Preliminary engineering is complete for both alternatives. During the course of estimating costs for the two options it became obvious that Option 2 was a more cost-effective and technically superior alternative. Preliminary engineering and cost estimates were completed for Option 1, but the option was not carried to the financial analysis phase.

In Option 3 the Solar Saturn turbine is replaced by the larger Solar Centaur turbine and the combustor/air heater enlarged accordingly. The reason for developing Option 3 is to produce a near-optimal system configuration with respect to electric generation in order that economic analysis can establish the viability of the electric generation portion of the overall system. Options 1 and 2, with their emphasis on a reduced scale for demonstration purposes, fail to provide an economically-appropriate scale. Firm cost estimates for the components of Option 3 were not solicited and the cost estimate is based on discussion with Applied Thermal Systems, rather than a firm quotation. Hence, the level of confidence in the cost estimate for Option 3 is reduced relative to those for Option 1 and Option 2.

The cost estimates have been aggregated in order to mask individual quotations from certain suppliers who requested that the confidentiality of quotations be maintained. Drawings for all options are located in Appendix B at the end of the report.

3.2.1 Option 1

Option 1 is based upon the use of a tubular recuperative heat exchanger located in the exit flue gas stream from a wet-fuel combustor. Drawing No. 87-50-002 shows the flow chart and flow data for Option 1, while Drawings No. 87-50-003 and 87-50-004 shows the plan and elevation views respectively.

The tubular recuperative heat exchanger is constructed in alloy 800H material in order to withstand the 760°C temperature. Air pressure can be contained within the tubes and a platework shell can be utilized for ducting of the flue gases. The seals can be welded at the shell penetration, producing a gas-tight enclosure.

The combustor unit consists of a Bigelow Liptack or similar wet cell type hot gas generator. The hot gases exiting the combustor at 1116°C (2040°F) are split into two streams; one stream is directed to the turbine tubular recuperative air heater after being tempered by air injection to a temperature of 1010°C

(1850°F), stream two is by-passed directly to the kiln hot oil heater. The feed gas to the oil heater is tempered to 616°C (1140°F) by the 538°C (1000°F) gases returning from the turbine air heater and the exhaust air at 487°C (900°F) from the gas turbine. These combined gas flows are then passed through the kiln oil heater where the temperature is reduced to 177°C (350°F); the gases enter the multi-clone gas cleaning system for removal of particulates before ejection from the stack via the induced draft fan.

The dry kiln oil heater system heats the thermal oil to 232°C (450°F) and pumps the oil through the heat exchangers in the kiln as required by the kiln drying schedules; the thermal oil returns to the oil heater at a temperature of 177°C (350°F). Control of the thermal oil temperature will be by a combination of tempering air dampers at the inlet to the oil heater on the gas side, and by diversion of the turbine exhaust air directly to the induced draft fan inlet. In addition, emergency vent stacks will be incorporated into the combustor for venting the hot gases and for increasing the excess air flow into the combustor. In this way flue gas temperatures can be reduced to protect the air heater tubing materials.

In this case the fuel consists of sawdust only and must be transported approximately 1500 feet from the conveyors collecting the sawdust in the mill to the kilns. The fuel handling system will consist of a short conventional belt conveyor to transport the sawdust from the head end of the existing conveyor to a storage pile. The pile will act as the buffer storage for weekends and other times when the mill is shut down, but kiln heat is still required. The quantity of fuel required for 48 hours of full operation is 200 tonnes, a conical pile 60 feet in diameter and 22 feet high. The fuel will be directed by a screw feeder to a pneumatic transfer feeder and pneumatically conveyed the 1500 feet to the 160 cubic metre capacity surge bin adjacent to the north side of one of the existing kilns. A metering screw feeds the 45 percent moisture fuel from the surge bin to the combustor at a rate of 9200 pounds per hour. Drawing No. 87-50-001 shows a site plan for the sawmill yard showing the location of the storage pile and transfer system from the storage area to the kiln location.

Table 3-2 presents the capital cost for Option 1. The capital cost estimate totals $3,600,000 for the cogeneration system; when one adds the fuel handling system cost of $150,000 and the retrofit cost of $350,000 for the two existing kilns, the total cost of Option 1 is $4,100,000 for the complete installation. Option 1 is not the preferred option for two reasons. First, the cost estimate for Option 1 is significantly greater than for Option 2, $4,100,000 as compared to $3,340,000. Second, a major technical risk exists with respect to the design, fabrication and cost of the tubular recuperative air heater. No suppliers we contacted were prepared to quote on the air heater; hence, the cost estimate is our own based on materials and an estimate of the fabrication labour. Further detailed investigation and comparison of existing installations is required to verify that a tubular metal heater could meet the required conditions of service.

For these reasons, Option 1 is not included in the short list of options considered in the Financial Analysis section of this report (Section 4.0).

TABLE 3-2

Option 1: Capital Cost Estimate

Fuel Handling System	
Fuel Transfer to Storage and Pneumatic Delivery System	$ 150,000
Cogeneration System	
Fuel surge bin	$ 25,000
Combustor (40mm Btu/hr)	450,000
Heat Exchanger (11mm Btu/hr)	450,000
Gas Turbine/Generator	975,000
Kiln Oil Heat Exchanger	250,000
I.D. Fans	25,000
Stack	60,000
Emergency Cooling Fan	20,000
Air Pipework	35,000
Ducting	35,000
Control Dampers	15,000
Multi-clones	45,000
Electrical & Instrumental	250,000
Civil/Structural	100,000
Installation and Insulation	250,000
Engineering and Project Management	250,000
Contingency	365,000
TOTAL	$3,600,000
Retrofit Existing Kilns (2)	
Kiln oil pumping, instrumentation and electrical	$ 100,000
Kiln heaters	250,000
TOTAL	$ 350,000
Overall Total	$4,100,000

Notes:

1. Heat Exchanger cost based on materials and an estimate of labour required to build unit. No quotations were received.

2. Cost of a new Solar Saturn gas turbine/generator estimated at 25 percent greater than the reconditioned unit quoted by Applied Thermal Systems (See Option 2 capital cost).

3.2.2 Option 2

Option 2 provides the same electrical and heat output as Option 1, but uses a different type of combustor and heat exchanger to do so. The combustor chosen for this study consists of a single cylindrical vessel incorporating a down-fired suspension burner unit, together with an integral air heater heat exchanger as supplied by Applied Thermal Systems Inc. of Oklahoma City, Oklahoma. The fuel for the Option 2 system consists of clean sawdust which is first dried to a moisture content of approximately 10 percent before entering the combustor unit. Drawing No. 87-50-005 shows the flow chart and flow data for Option 2, while Drawings No. 87-50-006 and 87-50-007 show the plan and elevation views, respectively, of the proposed system.

The heat exchanger has both a convective and a radiant section in order to heat the gas turbine compressor exit air to 760°C (1400°F) before entering the turbine. Provision is also made for emergency venting of both the combustor flue gases and the high pressure heated air before it enters the turbine. A distillate-fuelled combustor is provided to aid in start up of the system, but would be not used during steady-state operation.

Following expansion in the turbine, the air joins the flue gases from the combustor before passing into a kiln oil heater. This heat exchanger is used to provide a supply of hot thermal oil to the three lumber dry-kilns.

After leaving the kiln oil heater, the combined stream of combustor flue gases and turbine exhaust air passes through the fuel dryer and is used to dry the fuel to a moisture content of approximately 10 percent before going through a dust collector, an induced draft fan and then out the stack. A series of cyclones in the dust collector removes particulate from the flue gas stream and any carryover from the fuel dryer so that environmental regulations can be met.

Both a forced draft fan and an induced draft fan are provided so that a balanced draft can be maintained in the combustor independently of conditions imposed on the flue gas stream downstream of the combustor. By-pass ducting and dampers are also provided so that all or a portion of the combined stream of flue gases and turbine exhaust air can be routed around the kiln oil heater during times when the kiln heat requirements are less than the full design values.

The use of a single combustor vessel incorporating the down-fired suspension burner and turbine air heat exchanger has resulted in a compact system design. The complete cogeneration plant is located adjacent to one of the three lumber dry kilns, allowing pipe runs for the kiln hot oil system and the attendant heat losses to be kept to a minimum. The wet sawdust fuel is conveyed to the fuel bin by a pneumatic conveying system similar to Option 1, and the dry fuel is also blown from the dryer to the suspension burner located at the top of the combustor vessel. The relatively compact nature of the design has enabled the complete cogeneration plant to be located between one of the dry-kilns and an existing roadway.

A schematic outline of the major electrical connections and a motor list are shown in Drawing No. 87-50-009. The control console consists of four sections, one each for the turbine and combustor control systems, one for the electrical generator controls and one for auxiliary systems such as fuel handling and the turbine lube oil system. The largest motors required are those for the induced draft fan and for the fuel conveying system blower. Finally, a preliminary construction schedule is shown in Drawing No. 87-50-010. The total design and construction time is estimated to be seven months following the placement of a firm order. The items with the longest lead time, in addition to the gas turbine itself, are the combustor and the air heater heat exchanger. Both of these items would likely be purchased from a single vendor, however, which should reduce the overall lead time somewhat. It should be noted that the two weeks allowed for testing and commissioning is probably a bare minimum, given that the demonstration project would be the first of its kind.

Table 3-3 presents the estimated capital cost for Option 2. The capital cost totals $2,840,000 for the cogeneration system; when costs of the fuel handling system ($150,000) and the retrofit to the two existing dry kilns ($350,000) are added, the total cost is $3,340,000. Option 2 is the preferred option because of the lower capital cost when compared to Option 1 and because Applied Thermal Systems provided a firm quote for the combustor/air heater. The cogeneration system capital cost has been allocated between kiln heating ($1,430,000) and electric generation ($1,410,000) for the the purpose of economic analysis in the next chapter.

TABLE 3-3

Option 2: Capital Cost Estimate

Fuel Handling System	
Fuel Transfer to Storage and Pneumatic Delivery System	$ 150,000
Cogeneration System	
Combustor/Air Heater/Oil Heater Unit Complete with fuel preparation, fuel dryer, fans, multi-clones, ducting, stack, electrical and instrumentation (Applied Thermal Systems)	1,175,000
Solar Saturn Turbine (Applied Thermal Systems)	781,000
Civil/Structural	100,000
Installation & Insulation	250,000
Engineering and Project Management	250,000
Contingency	284,000
TOTAL	$2,840,000
Retrofit Existing Kilns (2)	
Kiln oil pumping, instrumentation and electrical	$ 100,000
Kiln heaters	250,000
TOTAL	$ 350,000
Overall total	$3,340,000

Allocation of Cogeneration System Cost Between Kiln Heating and Electric Generation

	Kiln-Heating	Electric Generation
Combustor/Air Heater/Oil Heater	$ 866,000	$ 309,000
Turbine	-	781,000
Civil/Structural	70,000	30,000
Installation & Insulation	200,000	50,000
Engineering & Project Management	150,000	100,000
Contingency	144,000	140,000
Total	$1,430,000	$1,410,000

3.2.3 Option 3

Both Option 1 and Option 2 utilize the Solar Saturn turbine (600kW at 760°C intake air) and are suitable designs for a demonstration-scale project. Option 3 represents a commercial-scale configuration for the Boston Bar mill, with heat available for three kilns and electrical generation near the mill's average requirement. This option is a scaled-up version of Option 2 where a Solar Centaur turbine (1800kW at 760°C intake air) replaces the smaller turbine. Other components will also need to be scaled-up to provide the increased heat required; specifically, the combustor increased to 55MM Btu/hour in order to supply the larger turbine. Other equipment such as the fuel dryer, the dust collectors, fans, etc. will need to be sized for the increased flows.

A flow chart for Option 3 is shown in Drawing No. 87-50-008. The heat balance for this option has not been conducted at the same level of detail as for Option 2, but the flow data is included to show the basis of the concept. The layout of the system is similar to that of Option 2, except that a kiln oil heater is no longer used. The thermal oil kiln heating system is replaced with a system of air-to-air heat exchangers in the kilns.

With the larger turbine, under most operating conditions there would be nearly sufficient heat in the turbine exhaust air stream alone to provide the required kiln heating. The use of turbine exhaust air alone would require excessive heat exchanger area in the dry kilns, however, so provision has been made to mix some flue gas with the turbine exhaust air before entering the kilns. Some cool tempering air may also be required to reduce the temperature at inlet to the heat exchangers to 420°C so that mild steel can be used for the kiln heat exchangers. When the energy content of the turbine exhaust air is greater than that required for kiln heating, a portion of it is routed directly to the stack using a bypass line.

The cost of the hot oil system (oil heater - $250,000, oil pump and transfer to kiln - $100,000 and in-kiln oil/air heat exchangers - $250,000, total $600,000) is replaced by in-kiln air-to-air heat exchangers estimated to cost $200,000.

Capital costs for Option 3 are shown in Table 3-4. This estimate is based on discussions with Applied Thermal Systems, the major supplier of Option 2, and on the firm quotation for Options 1 and 2. Hence, the level of confidence in Option 3 capital cost estimates is lower than for Options 1 and 2.

TABLE 3-4

Option 3: Capital Cost Estimate

Fuel Handling System	
Fuel Transfer to Storage and Pneumatic Delivery System	$ 150,000
Cogeneration System	
Combustor/Air Heater Complete with fuel preparation, fuel dryer, fans, multi-clones, ducting, stack, electrical and instrumentation (Applied Thermal Systems)	1,200,000
Solar Centaur Turbine (Applied Thermal Systems)	1,400,000
Civil/Structural	150,000
Installation & Insulation	350,000
Engineering and Project Management	350,000
Contingency	350,000
TOTAL	$3,800,000
Retrofit Existing Kilns (2)	
Kiln heaters	$ 200,000
TOTAL	$ 200,000
Overall Total	$4,150,000

Allocation of Cogeneration System Cost Between Kiln Heating and Electric Generation

	Kiln-Heating	Electric Generation
Combustor/Air Heater	$ 625,000	$ 575,000
Turbine	-	1,400,000
Civil/Structural	75,000	75,000
Installation & Insulation	200,000	150,000
Engineering & Project Management	150,000	200,000
Contingency	150,000	200,000
Total	$1,200,000	$2,600,000

The capital cost estimate for Option 3 has been allocated between kiln drying and electric generation as in Option 2. This allocation provides the basis for estimating the economic viability of electric generation with a commercial-scale cogeneration system.

3.3 Further Design Investigations

The equipment selected in Phase II is directly related to the need for proven equipment and for a demonstration scale of project. Hence, the fluid-bed from Fluidyne Corporation of Minneapolis as originally specified in Phase I, was replaced with the suspension-fired unit with integral air heater as supplied by Applied Thermal Systems of Oklahoma City. The fluid-bed was not pursued because it was felt that the unit was still experimental, and that silica build-up on the tube surface of the in-bed heat exchanger could be a problem given that wood wastes would be the fuel. The Applied Thermal Systems design appears to meet the requirements of the cogeneration sytem in a cost-effective manner; other combustor manufacturers were asked to quote, but no other cost-effective approach to a combustor/air heater combination was forthcoming. The one weakness of the Applied Thermal system is that a dry fuel is required for the suspension firing; hence, the system requires additional fuel preparation and a fuel dryer. Although we generally feel that the Applied Thermal Systems approach is a cost-effective technical solution to the combustor/air heater requirement, we would recommend that the fiuld-bed approach be re-evaluated in the next phase.

Phase I selected the Kawasaki Model MIT gas turbine, distributed in North America by Cullen Detroit Diesel Allison Limited of Vancouver. The turbine selected in Phase II is the Saturn model of Solar Turbines Inc. of San Diego, California. There are two reasons for selecting Solar's equipment - the Saturn model is an appropriate size for a demonstration project and is designed with ducting for recuperated operation. The Solar turbines are relatively expensive, however, and we would recommend that other turbines be evaluated in the next phase. Cullen Detroit Diesel Allison Limited have recently indicated to us that

the Allison 501 turbine may soon be available in an external firing configuration. Both the Kawasaki and Allison turbines should be evaluated along with the Solar turbines in the next phase.

Another aspect which deserves further study is the manner in which heat is provided from the cogeneration system to the dry kilns. Two schemes have been examined in this report, one using a hot-oil heat transfer system and one using air-to-air heat exchangers in the kilns. Indirect heating of the kilns was used in both cases to permit individual control of both temperature and humidity to be obtained. Kiln heating experts felt that this was desirable in order to maintain careful control of drying schedules and to prevent excessive splitting and checking of the lumber. A much simpler and more cost-effective system could be obtained, however, by ducting turbine exhaust air directly into the dry kilns without the use of any form of heat exchanger. To maintain the appropriate kiln relative humidity a separate humidity control system could be adopted. This aspect should be explored further in the next phase in order to reduce the cost and complexity of the overall cogeneration system.

4.0 FINANCIAL ANALYSIS

Based upon estimated capital and operating costs for Option 2 and Option 3, this section analyzes the financial feasibility of the systems under a variety of conditions. The viability of the electrical generation side of the cogeneration system is examined separately from that of the overall system. In order to do this, the marginal revenues from electrical generation are weighed against the incremental cost of adding the electrical generation portion to a wood-fired kiln drying system.

Two separate and essentially different financial analyses are undertaken. For Option 2, the analysis is confined to determining the financial results in a demonstration project with electric generation of 600 kW proceeding at the Boston Bar sawmill. For Option 3, the analysis is broadened and the financial results are estimated for a commercial scale of operation (1800 kW) at other locations - specifically at locations where the price of electric energy is more expensive.

4.1 Financial Analysis Assumptions

In analyzing the financial feasibility of Option 2 and Option 3, assumptions must be made concerning a number of variables. These include:

- the quantities of fuel and electricity displaced;
- the cost of fuel and electricty displaced;
- future energy price escalation rates;
- debt/equity ratio;
- loan rate and amortization term;
- general inflation rate;
- the availability of government grants to encourage construction of a demonstration project.

In order to facilitate analysis of the sensitivity of the cogeneration system to changes in these variables, a computer model incorporating all of these factors was developed to calculate the after-tax internal rate of return and net present value.

Assumptions concerning these factors are discussed separately:

a) Quantities of Fuel and Electricity Displaced

The cogeneration system has been designed to provide all of the kiln drying heat requirements of the Boston Bar sawmill when additional kiln drying capacity is installed in 1988. At this time, target kiln-dried lumber production from the mill will be about 60 million board feet annually. If propane were to continue to be used to dry this level of output, annual propane consumption would be in the vicinity of 84 terajoules, given an average drying requirement of 1.4 gigajoules per thousand board feet of output. This quantity of propane is assumed to be displaced by the sytem.

The turbine generator will displace 600 kW (Option 2) or 1800 kW (Option 3) of electric power when the whole sawmill is operating - i.e., 5 days per week, 24 hours per day, for 240 days per year. During weekends, when only the dry kilns require power, it is estimated that 300 kW will be displaced one day per week, 24 hours per day, 50 days per year. On this basis, the cogeneration system will displace about 3,800 MWh annually, and reduce peak billing demand by 600 kW with Option 2.

b) Fuel Price

Propane Prices

A propane price of $8.00 per gigajoule (20.4 cents per litre) has been used as the starting point in this analysis. The wholesale price of propane at Edmonton, the main basing point for western Canada, has been very low over the last year, barely covering the cost of production. With new sources of propane (such as

Alaska North Slope "spiked" crude oil) recently coming on-stream, it is expected that a surplus of propane will continue throughout most of North America for the next few years. As natural gas and crude oil prices move higher, however, the increased use of propane as petrochemical feedstock will also exert an upward pressure on propane prices. The base year propane price has been escalated at the following real rates over the 20 year life of the project.

	Low Case	Base Case	High Case
Years 1 to 5	0%	1%	2%
Years 6 to 10	1%	2%	3%
Years 11 to 20	2%	3%	5%

Electricity Rates

The present B.C. Hydro rates for a sawmill of the scale of the Boston Bar mill are as follows:

Demand charge	$6.01/peak kW demand/month
Energy charge	2.64 cents per kWh

Over the forecast period, the following electric rate escalation scenarios have been used in the financial analysis of the cogeneration system.

	Low Case	Base Case	High Case
Years 1 to 5	0%	0%	0%
Years 6 to 10	0%	1%	2%
Years 11 to 20	0%	1%	3%

With substantial surplus generating capacity in the B.C. Hydro system, no real increases are expected for the next 5 years in any of the cases considered. Over the longer term growth of domestic demand could require costly new capacity to be constructed, resulting in considerable price increases.

Sale of Surplus Electricity

At present, B. C. Hydro will not purchase power from industrial generators on its integrated grid system, as it has a surplus of capacity. This could change in the future, however, as a result of several factors:

(i) Reduction of the surplus capacity, resulting in the willingness of B.C. Hydro to purchase power from any industrial generators on the integrated grid.

(ii) As the Boston Bar transmission line becomes increasingly capacity-critical, B. C. Hydro might be willing to make an exception to its general policy and buy back power from the Boston Bar mill.

(iii) With planned deregulation of electrical generation in B.C., surplus power from the mill could be wheeled through the B.C. Hydro system and sold to a third party.

A sensitivity case is therefore considered in which the mill generates power at its full output of 600 kW and sells the surplus power at current rates. At 80 percent capacity factor, the system would generate 4,205 MWh of electric energy annually.

c) Financial Assumptions

The following conditions are used as a basis for project financing: 60/40 debt/equity ratio; 10-year loan amortization; 11 percent interest rate. The feasibility of the project is also presented on the basis of 100 percent equity financing to permit comparability with alternative investment opportunities evaluated on this basis.

Other standard financial assumptions, as listed in Tables 4-1 and 4-3, include a project lifetime of 20 years, a corporate tax rate of 46 percent, and a 4 percent general inflation rate. The latter factor is applied to all parameters except the loan repayment which, of course, is fixed over the 20-year term.

This project qualifies for an accelerated depreciation allowance (25%, 50%, 25% over 3 years) under Class 34 of the Capital Cost Allowance system, which includes equipment used for the generation of electricity or the production or distribution of heat. In addition, an investment tax credit amounting to 3 percent of the capital cost is available in the southern half of British Columbia. This tax credit, which will be ended after 1988, is subtracted from the capital cost before calculating the allowable depreciation deductible from before-tax income.

4.2 Option 2 Financial Analysis Results

Table 4-1 summarizes the inputs to the base case financial analysis of Option 2. Table 4-2 presents the results of the Option 2 financial analysis, not only for the base case assumptions, but also for a variety of other cases represented by different combinations of assumptions.

The overall system is shown to generate an attractive rate of return in all of the cases considered. By comparison, the rate of return on the incremental investment required for electrical generation equipment is very low without substantial capital grants. Sale of surplus power would only marginally improve the rate of return on a generator of this scale, given the already-high degree of utilization in a mill operating on a 3-shift per day basis.

The low return on the incremental electric generation can be traced directly to the 600 kW demonstration size level. In order to make a demonstration project attractive to a commercial operator, a sizable grant is needed from government funding agencies and/or the capital costs need to be reduced. Cooperative arrangements whereby a manufacturer could be persuaded to loan (or lease for a relatively short period of time) a suitable turbine-generator would be one means of reducing the capital cost of a demonstration project.

TABLE 4-1: BASE CASE ASSUMPTIONS FOR FINANCIAL ANALYSIS, OPTION 2

CAPITAL AND OPERATING COSTS

Capital Cost:	Overall system	$3,340,000
	Electric gen.	$1,410,000
Ann. Operating Cost:	Overall system	$ 207,000
	Electric gen.	$ 80,500

REVENUE ASSUMPTIONS

			Unit Cost	Annual Revenue (Year 0)
Propane displaced:	(GJ)	84,000	$8.00/GJ	$672,000
Electricity displaced:	Energy (MWh)	3,800	$0.0264/kWh	$100,320
	Demand (kW)	600	$6.01/kW/mon.	$ 43,272
	Subtotal			$143,592
	TOTAL			$815,592

ENERGY PRICE ESCALATION

	% per annum (real)
Propane:	
Year 1 - 5	1%
Year 6 - 10	2%
Year 10 - 20	3%
Electricity:	
Year 1 - 5	0%
Year 6 - 10	1%
Year 10 - 20	1%

FINANCIAL ASSUMPTIONS

Debt	60%
Equity	40%
Project Life	20 years
Depreciation	3 years (25%, 50%, 25%)
Investment tax credit	3% of capital cost
Tax Rate	46%
General Inflation Rate	4%
Loan rate	11%
Loan term	10 years

TABLE 4-2: SUMMARY OF FINANCIAL ANALYSIS RESULTS, OPTION 2

Case No.	Case Description	Changes to Base Case Assumptions in Table 4-1	After-Tax IRR: *	
			Overall System	Electric Gen. Only
1	Base Case **	None	36.5%	2.1%
2	10 year Project Life	Same as 1, only 10 year project life instead of 20 years	32.8%	negative
3	Low energy price escalation	No real increase in energy prices over forecast period	34.7%	negative
4	High energy price escalation	Increases as detailed in Section 4.2	38.3%	4.8%
5	Internal financing	100% equity financing	20.3%	3.9%
6	Surplus power sold	Same as 1, but surplus power sold at 2.64 cents/kWh	37.1%	4.4%
7	Government grant	$500,000 reduction in capital cost	42.8%	9.4%
8	Government grant	$300,000 reduction in capital cost	40.0%	5.9%

* Note that IRR is in the context of a 4% general inflation rate.

** See Table 4-1 for Base Case Assumptions.

4.3 Option 3 Financial Analysis Results

Option 3 is intended to illustrate the potential of the cogeneration system at a commercial scale level. Specifically, Option 3 will provide heat for three kilns (drying capacity of 60 million board feet per year) and 1800 kW, which is near the mill's average electrical requirement.

Table 4-3 summarizes the input parameters to the financial analysis of Option 3. Two key changes from the assumptions for Option 2 should be noted. First, the electric generation portion of the system is assumed to assumed to operate 350 days per year at full output of 1800 kW and the output is valued at $.05 per kWh. The assumption is that the local electric utility will buy surplus power at $.05 per kWh. Also, natural gas (at $4.50 per GJ) is assumed as the kiln heating fuel. In effect, the Option 3 base case analysis would be representative of a northern Ontario location. A slightly higher rate of kiln fuel price escalation is assumed during the first 10 years of the project lifetime than in the Option 2 analysis.

Table 4-4 presents the Option 3 financial results. In the Base Case the after-tax rates of return on the electric generating portion of the system (42.2 percent), and on the overall system (39.8 percent), are very acceptable. The reasons for the excellent return on the electric generation portion of the system (compared to Option 2) are the increased scale of output, the assumption that the system can be run continously, and that surplus power sold to the local utility at a reasonable price.

In Case 4, given the lower electric rates that prevail in B.C. and the present inability to sell surplus power, the return on the electric generation portion of the system for a Boston Bar location is only 17.8 percent, a barely adequate level of return. If the mill could sell its surplus power to either B.C. Hydro or a third party, the return would increase to 27.8 percent, even at the low rates which presently prevail in B.C. A 25 percent increase in capital cost (Case 6) reduces the after-tax IRR to 34.1 percent for the electric generation portion of the system, a level that is still quite acceptable.

In summary, the financial analysis of Option 3 shows that a commercial scale cogeneration system of this type has the potential to produce attractive rates of return under a variety of conditions.

TABLE 4-3: BASE CASE ASSUMPTIONS FOR FINANCIAL ANALYSIS, OPTION 3

CAPITAL AND OPERATING COSTS

Capital Cost:	Overall system	$4,150,000
	Electric gen.	$2,600,000
Ann. Operating Cost:	Overall system	$ 247,500
	Electric gen.	$ 140,000

REVENUE ASSUMPTIONS

			Unit Cost	Annual Revenue (Year 0)
Natural gas displaced:	(GJ)	84,000	$4.50/GJ	$378,000
Electricity displaced:	Energy (MWh)	15,120	$0.05/kWh	$756,000
	Demand (kW)	0	$0.00/kW/mon.	0
	Subtotal			$756,000
	TOTAL			$1,134,000

ENERGY PRICE ESCALATION

	% per annum (real)
Natural Gas:	
Year 1 - 5	2%
Year 6 - 10	3%
Year 10 - 20	3%
Electricity:	
Year 1 - 5	0%
Year 6 - 10	1%
Year 10 - 20	1%

FINANCIAL ASSUMPTIONS

Debt	60%
Equity	40%
Project Life	20 years
Depreciation	3 years (25%, 50%, 25%)
Investment tax credit	3% of capital cost
Tax Rate	46%
General Inflation Rate	4%
Loan rate	11%
Loan term	10 years

TABLE 4-4: SUMMARY OF FINANCIAL ANALYSIS RESULTS, OPTION 3

Case No.	Case Description	Changes to Base Case Assumptions in Table 4-3	After-Tax IRR: *	
			Overall System	Electric Gen. Only
1	Base Case **	None	42.2%	45.3%
2	10 Year Life	10 Year Life instead instead of 20 years	39.8%	43.5%
3	Propane	Same as Base Case, only propane @ $8.00/GJ replaces natural gas	55.7%	45.3%
4	Boston Bar Location	Electric power at $0.0264 per kWh and $6.01 per kW per month, propane at $8.00/GJ	41.0%	17.8%
5	Internal financing	100% equity financing	22.5%	23.4%
6	Capital Cost Increases	Capital cost assumed to be 25% higher than Base Case	31.7%	34.1%

* Note that IRR is in the context of a 4% general inflation rate.

** See Table 4-3 for Base Case Assumptions.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In the context of the system design, preliminary engineering, and the budget prices developed, we feel that the indirect-fired cogeneration approach is technically and economically sound. The cogeneration system proposed could, at a commercial scale of operation, result in a sawmill being completely energy self-sufficient. All of the heat required for lumber drying, as well as all of the electricity required by the mill, could be provided by wood-waste which is currently either land-filled or incinerated in most mills.

One of the key technical problems, i.e., a workable combustor/air heater arrangement, appears to be successfully addressed by the combined unit quoted by Applied Thermal Systems. The financial results for Option 3, a commercial scale of operation, are also encouraging; for example, if the electric output is valued at 5¢ per kWh the after-tax rate of return on the electric generation portion of the system is 45 percent. A successful demonstration project could result in the widespread adoption of cogeneration in sawmills both in Canada and abroad, particularly in developing countries where the financial return would be substantially higher.

The prospect that the preliminary engineering for the Boston Bar sawmill would lead directly to a demonstration project at the site is unlikely to occur. The financial result for Option 2, an after-tax rate of return of 2 percent on the electric generation portion, shows the need for outside support for the demonstration. The reduced scale of operation associated with the demonstration and the level of electric energy rates in British Columbia (less than 3.0¢/kWh average for sawmills) contribute to the poor financial results. Still, given the technical risks, the 600 kW scale is appropriate for a first project utilizing the indirect-fired approach and the associated equipment.

5.2 Phase III Recommendations

We feel that the results of Phase II are positive, and that the next step is to identify an appropriate demonstration site and to organize a demonstration project.

A successful demonstration site will be a sawmill with the following characteristics:

- Relatively expensive electric energy. Electricity rates on the main grid in British Columbia are inexpensive. Ideally, the site would be at a location with higher electric energy rates; for instance in Ontario, the Maritimes, or off the main grid in British Columbia.

- Either a good load factor or a market for surplus power. Ontario Hydro, for example, will buy electric power from independent producers at about 5¢/kWh.

- Institutional Support - the demonstration project should have general support from the local electric utility, governments, and equipment manufacturers (eg., turbine suppliers).

- A sawmill owner-operator who is personally interested in the concept.

The major tasks of Phase III are:

- Identify a short list of suitable sites and industrial participants.

The approach would be to inform people in the sawmilling and bioenergy sectors that a candidate is being sought for a demonstration. Discussions with government personnel active in bioenergy R&D and consulting engineers specializing in bioenergy, promotion of the demonstration concept in the forest industry and bioenergy trade press, and consultation with equipment manufacturers are all appropriate actions.

- Identify funding alternatives.

A demonstration project carries an element of technical and economic risk. Clearly, an industrial participant needs to be shielded to a certain degree from these risks. Different alternatives for reducing risk are R & D grants from government programs, government loan guarantees, and tax incentives, including accelerated depreciation and tax credits. A wide range of funding alternatives for a demonstration project would be investigated.

Also, equipment manufacturers would be approached to ascertain their interest in supporting a project.

- Evaluate the short list of sites.

A short list of three or four sites would be selected for evaluation and ranking. We would not carry out full preliminary engineering studies, but flow sheets and mass and energy balances would be necessary. Capital costs would be based on data collected in Phase I and II. Financial analysis similar to Phase II would be performed.

- Structure a demonstration project.

  For the best site a formal plan for a demonstration would be developed. A key component of the plan would be the funding for the demonstration. Also, participants in the demonstration and their roles - equipment suppliers, engineering support - would need to be identified. The objective of the formal plan is to provide the necessary documentation to allow potential demonstration participants to make commitments. The formal plan would, in effect, be the final report for Phase III.

APPENDIX A

MARKET ANALYSIS FOR COGENERATION SYSTEM

APPENDIX A

MARKET ANALYSIS FOR COGENERATION SYSTEM

In addition to analyzing the feasibility of the cogeneration system for the specific site considered herein, Energy, Mines and Resources Canada requested that the overall market potential for a cogeneration system of this type also be briefly examined. Table 2-1 of the Phase I report presented an overview of the quantitites of purchased energy used in Canadian sawmills and planing mills during 1983. This table, however, gave no indication of the numbers of mills associated with the quantities of energy used, nor how many of these mills might be of a sufficient scale to be considred as potential markets for a cogeneration system of this type.

Canadian Market

A special data request was made to Statistics Canada to provide more detailed fuel and electricity use information for Canadian sawmills. Statistics Canada was able to supply unpublished information as to the number of sawmills by fuel use range, along with their associated fuel and electricity use for the 1985 calendar year. Data were supplied not only for Canada as a whole, but also for British Columbia and Ontario, as shown in Table A-1.

The quantities of fuels shown in this table are virtually all used for kiln drying. The energy use ranges were intended to represent the following ranges of kiln-dried lumber production, based upon an average factor of 1.6 GJ per thousand board feet of kiln-dried output:

Energy Use Range (GJ/ann)	Kiln-dried Lumber Output (million fbm/ann)
40,000 - 80,000	25 - 50
80,001 - 160,000	51 - 100
More than 160,000	More than 100

TABLE A-1: DISTRIBUTION OF PURCHASED SAWMILL ENERGY USE BY VOLUME RANGE, 1985

ALL CANADA	NAT.GAS	HFO	LPG	TOTAL	% OF CANADA TOTAL
40,000 TO 80,000 GJ/ANN:					
No. of mills in range	20		4	24	30.0%
Fuel use of mills (Terajoules)	841		394	1,235	16.1%
Electricity use of mills ('000 MWh)	156		54	210	19.0%
80,001 TO 160,000 GJ/ANN:					
No. of mills in range	27		3	30	37.5%
Fuel use of mills (Terajoules)	2,074		435	2,509	32.8%
Electricity use of mills ('000 MWh)	269		34	303	27.4%
More than 160,000 GJ/ANN:					
No. of mills in range	21			21	26.3%
Fuel use of mills (Terajoules)	3,734			3,734	48.8%
Electricity use of mills ('000 MWh)	512			512	46.3%
TOTAL - ALL RANGES					
No. of mills in range	68	5	7	80	100.0%
Fuel use of mills (Terajoules)	6,648	179	829	7,657	100.0%
Electricity use of mills ('000 MWh)	937	80	88	1,106	100.0%
BRITISH COLUMBIA					
40,000 TO 80,000 GJ/ANN:					
No. of mills in range	10			10	12.5%
Fuel use of mills (Terajoules)	414			414	5.4%
Electricity use of mills ('000 MWh)	86			86	7.8%
80,001 TO 160,000 GJ/ANN:					
No. of mills in range	19			19	23.8%
Fuel use of mills (Terajoules)	1,485			1,485	19.4%
Electricity use of mills ('000 MWh)	186			186	16.8%
More than 160,000 GJ/ANN:					
No. of mills in range	16			16	20.0%
Fuel use of mills (Terajoules)	3,011			3,011	39.3%
Electricity use of mills ('000 MWh)	452			452	40.8%
TOTAL - ALL RANGES					
No. of mills in range	45			45	56.3%
Fuel use of mills (Terajoules)	4,910			4,910	64.1%
Electricity use of mills ('000 MWh)	723			723	65.4%
ONTARIO					
40,000 TO 80,000 GJ/ANN:					
No. of mills in range	7			7	8.8%
Fuel use of mills (Terajoules)	289			289	3.8%
Electricity use of mills ('000 MWh)	60			60	5.4%
More than 80,000 GJ/ANN:					
No. of mills in range	7			7	8.8%
Fuel use of mills (Terajoules)	621			621	8.1%
Electricity use of mills ('000 MWh)	79			79	7.1%
TOTAL - ALL RANGES					
No. of mills in range	14			14	17.5%
Fuel use of mills (Terajoules)	910			910	11.9%
Electricity use of mills ('000 MWh)	139			139	12.6%

See next page for explanatory notes to table.

NOTES TO TABLE A-1:

1. Source: Statistics Canada, special compilation from Annual Census of Manufacturers. This data is published in more aggregate form in Statistics Canada's annual Catalogue 57-208, "Consumption of purchased fuel and electricity by the manufacturing, mining, logging and electric power industries".

2. Survey coverage: Statistics Canada's survey of energy use by type covers virtually all sawmills of significance. In 1985, for example, the 380 sawmills that were surveyed accounted for more than 92 percent of total sawmill output in Canada. Of these 380 mills, only 80 were large enough users of dry kiln fossil fuels to fall into the ranges covered in Table A-1.

Table A-1 shows the fuel use of all mills in Canada in which the output is kiln-dried with energy sources other than wood waste or electricity and use more than 40,000 GJ per year. A cogeneration system of this type would not logically be retrofitted into mills already using wood waste or electricity for kiln-drying, so they have not been included in Table A-1.

While the 80 mills included in Table A-1 represent only 18 percent of the total number of mills covered by the Statistics Canada survey, they accounted for about 43 percent of purchased electricity and 62 percent of the quantity of dry kiln fossil fuels used by all sawmills included in the survey during 1985. Of the mills included in Table A-1, energy use was concentrated in the larger mills, as about one-quarter of the mills accounted for almost one-half of total fuel and electricity consumption.

Geographically, kiln drying fossil fuel use is shown to be concentrated in British Columbia, as 56 percent of the larger mills using fossil fuels for kiln drying consume almost two-thirds of total national fuel and electricity use by such mills. With some of the lowest electricity rates in the world, however, cogeneration is not nearly as economically attractive in British Columbia as in many other jurisdictions.

For example, there are fewer sawmills in Ontario which might be of the appropriate scale for a cogeneration system of this type. However, Ontario is probably a better potential market for sawmill cogeneration, given its higher power rates and the willingness of Ontario Hydro to purchase surplus power at an attractive rate.

Quebec is not considered to be a logical market area for sawmill-scale cogeneration, given its low power rates combined with the fact that many of its larger mills have already displaced kiln drying fossil fuels with either wood wastes or electricity. On the other hand, the system may be more feasible in New Brunswick where both power and kiln drying fossil fuels are more expensive than in British Columbia.

International Markets

In many respects, a cogeneration system of this type would be more attractive in foreign countries than it would be in Canada. Factors that would make the proposed system attractive in other countries include the following:

1. Lack of electric power distribution infrastucture: in many developing countries with forest resources, the lack of electric power is a very real constraint to the exploitation of these resources. Sawmills in such regions must therefore be self-sufficient in both electric power generation and dry kiln heat production.

2. Lack of sufficient cooling water for steam-based cogeneration: water in many parts of the world is in much scarcer supply than in most parts of Canada. In such regions conventional steam cogeneration systems may either be totally impracticable, or require the addition of costly cooling systems. A gas turbine system requiring no water would permit the establishment of cogeneration plants and sawmills in locations where they otherwise might not be feasible.

3. Higher electric power rates: major sawmilling regions of Canada, particularly British Columbia and Quebec, have some of the lowest power rates in the world. In contrast, many other sawmilling regions such as the United States have much higher rates which would greatly enhance the economic viability of the proposed system.

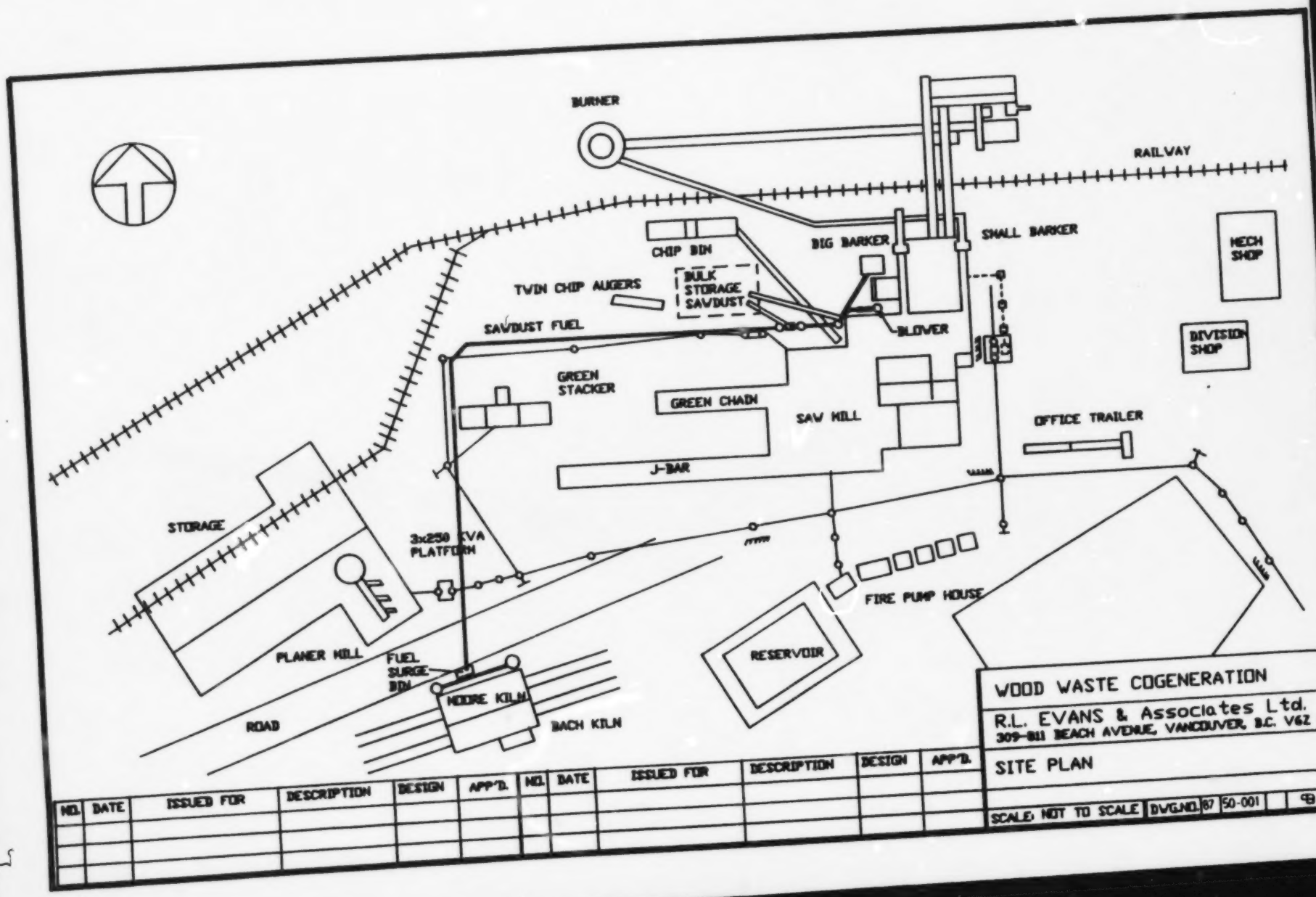
4. Utility purchase of surplus power: the mandatory purchase of surplus power generated by industry at utilities' avoided generation costs has been an effective incentive to increased industrial cogeneration of power in the United States.

The foregoing factor, combined with the generally higher electric rates and the large number of sawmills in the U.S., makes that country one of the more attractive markets for the system proposed herein. In addition, the relative position of the Canadian dollar would also favour supply of system components from Canada.

Aside from the United States, less developed countries such as Chile also offer considerable potential for this type of cogeneration system. With extensive forestry plantations maturing over the next decade, more sawmills will have to be built in Chile to process the growing annual harvest. Some of this timber may be in regions that are considerable distances from the national power grid, in which cases a cost-effective sawmill cogeneration system could be a very marketable item. Other countries in South America (Brazil and Peru, for example) and in Africa, where electric power is not widely distributed and water is often in short supply, are also seen as potential markets for a system of this type.

APPENDIX B

DRAWINGS



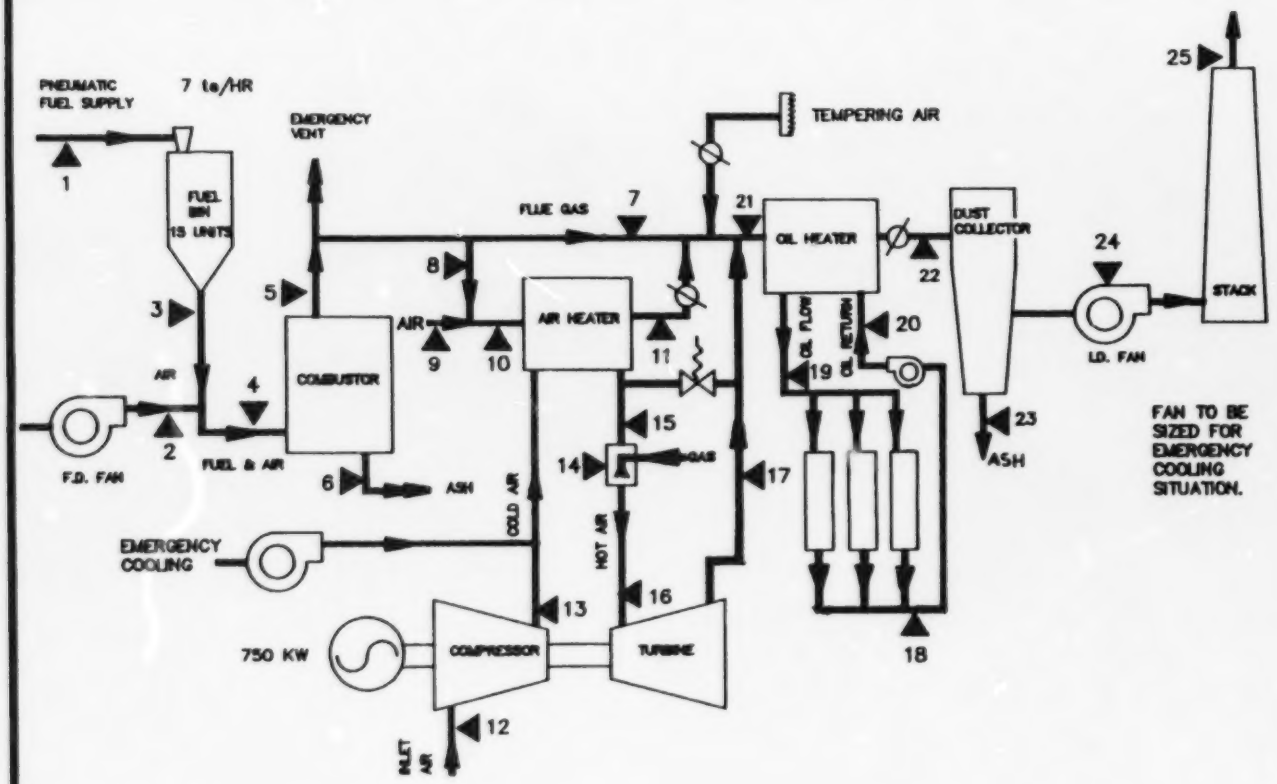
NO.	DATE	ISSUED FOR	DESCRIPTION	DESIGN	APP'D.	NO.	DATE	ISSUED FOR	DESCRIPTION	DESIGN	APP'D.

WOOD WASTE COGENERATION

R.L. EVANS & Associates Ltd.
309-811 BEACH AVENUE, VANCOUVER, B.C. V6Z 2E9

SITE PLAN

SCALE: NOT TO SCALE | DWG.NO. 87 50-001 | 98



PRELIMINARY FLOW CHART FOR SAWMILL COGENERATION / SAWDUST FUEL

FLOW DATA

PT.	ENERGY FLOW (a) MBTU/HR	MW	MASS FLOW LB/SEC	MASS FLOW KG/SEC	TEMPERATURE °F	TEMPERATURE °C	PRESSURE LB/IN²	PRESSURE KPA
1			4.3	1.95	60	15.6	15	101
2			13.6	6.18	60	15.6	15	101
3			2.56	1.16	60	15.6	15	101
4	39.25	11.5	16.13	4.72	60	15.6	16	108
5	33.36	9.8	16.13	4.72	2040	1116	15	101
6			0.014	.006	2040	1116	15	101
7	11.2	3.28	5.42	2.46	2040	1116	14	94
8	22.17	6.5	10.7	4.86	2040	1116	14.5	98
9			1.14	.52	60	15.6	14	94
10	22.17	6.5	11.8	5.36	1850	1010	15	101
11	10.87	3.19	11.8	5.36	1000	538	14	94
12			13.4	6.09	60	15.6	15	101
13	5.4	1.58	13.4	6.09	491	255	75	517
14	1.7	0.5	.02	.009	60	15.6	15	101
15	16.7	4.89	13.4	6.09	1400	760	72	507
16	18.8	5.51	13.4	6.09	1531	833	72	507
17	10.4	3.05	13.4	6.09	909	487	15	101
18								
19	37.3	10.9	123.4	55.9	450	232	25	168
20	13.3	3.9			350	177		
21	32.5	9.52	30.66	13.9	1140	616	14	94
22	6	1.76	30.66	13.9	350	177	13	91
23			.014	.006	300	149	15	101
24			30.66	13.9	300	149	15.5	103
25			30.66	13.9	300	149	15	101

(a) NOTE:
Based on (enthalpy)h=0 @ 80 °F

NO.	DATE	ISSUED FOR	DESCRIPTION	DESIGN	APP'D.	NO.	DATE	ISSUED FOR	DESCRIPTION	DESIGN	APP'D.
A	11.3.87	PHASE II REPORT	OIL DATA REV.								

WOOD WASTE CO-GENERATION

R.L. EVANS & Associates Ltd.
309-811 BEACH AVENUE, VANCOUVER, B.C. V6Z 2B5

PRELIMINARY FLOW CHART FOR SAWMILL COGENERATION/SAWDUST FUEL

OPTION 1

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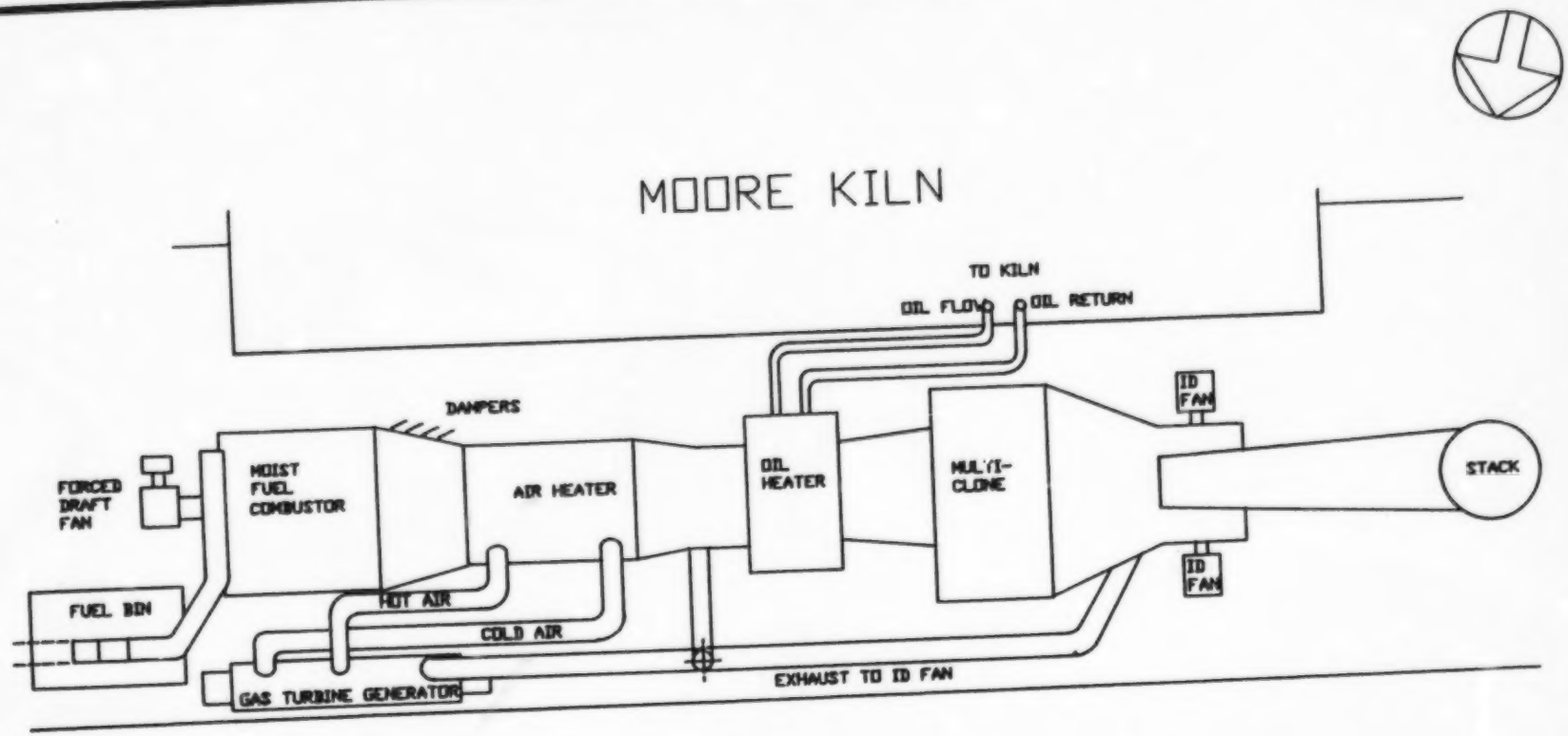

NO.	DATE	ISSUED FOR	DESCRIPTION	DESIGN	APP'D.	NO.	DATE	ISSUED FOR	DESCRIPTION	DESIGN	APP'D.

WOOD WASTE COGENERATION

R.L. EVANS & Associates Ltd.
209-811 BEACH AVENUE, VANCOUVER, B.C. V6Z 2E9

SAWMILL COGENERATION PLANT PLAN

OPTION 1

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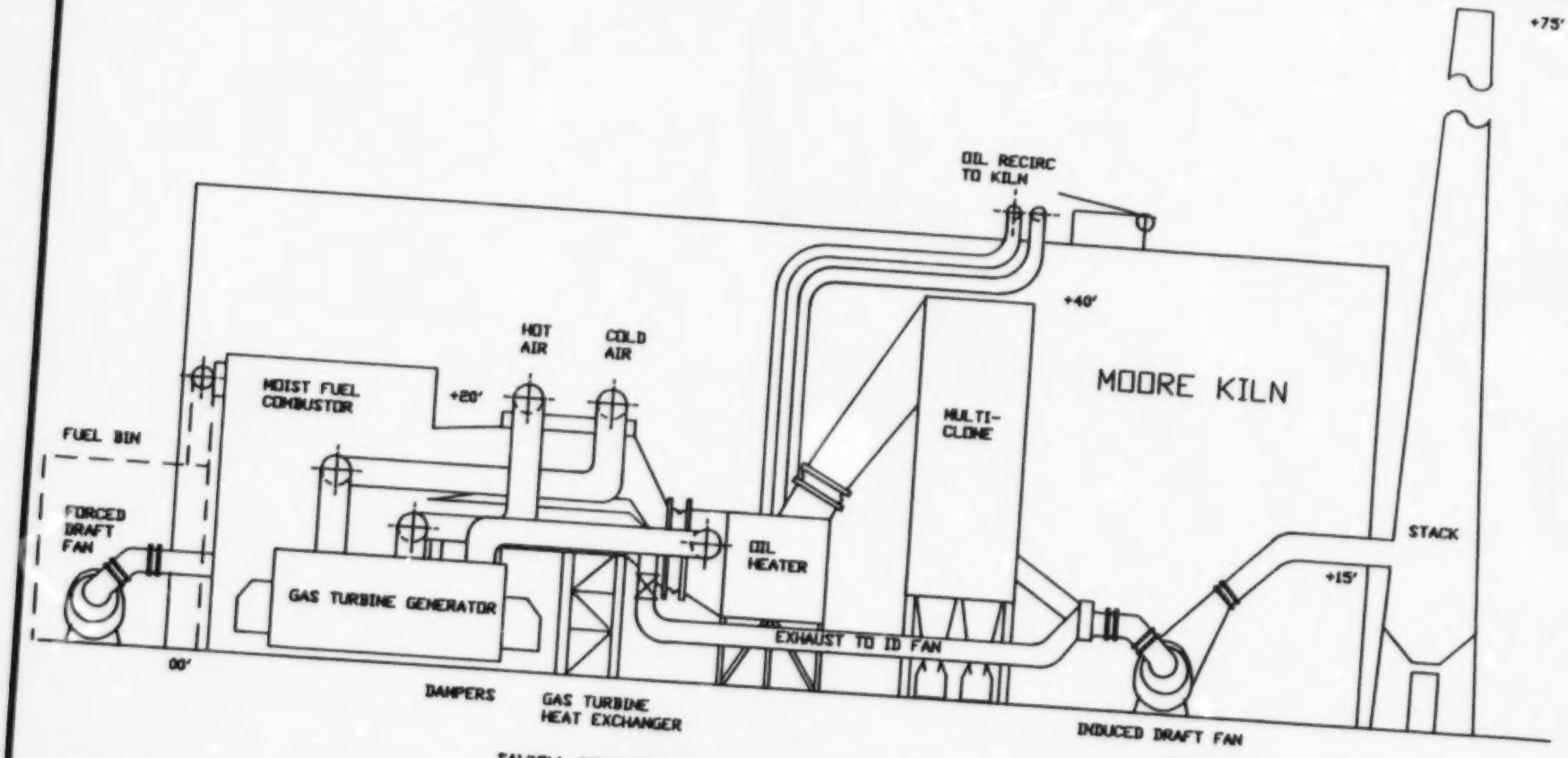

SAWMILL COGENERATION PLANT ELEVATION

NO.	DATE	ISSUED FOR	DESCRIPTION	DESIGN	APP'D.	NO.	DATE	ISSUED FOR	DESCRIPTION	DESIGN	APP'D.

WOOD WASTE CO-GENERATION

R.L. EVANS & Associates Ltd.
309-811 BEACH AVENUE, VANCOUVER, B.C. V6Z 2B5

SAWMILL COGENERATION PLANT ELEVATION

OPTION 1

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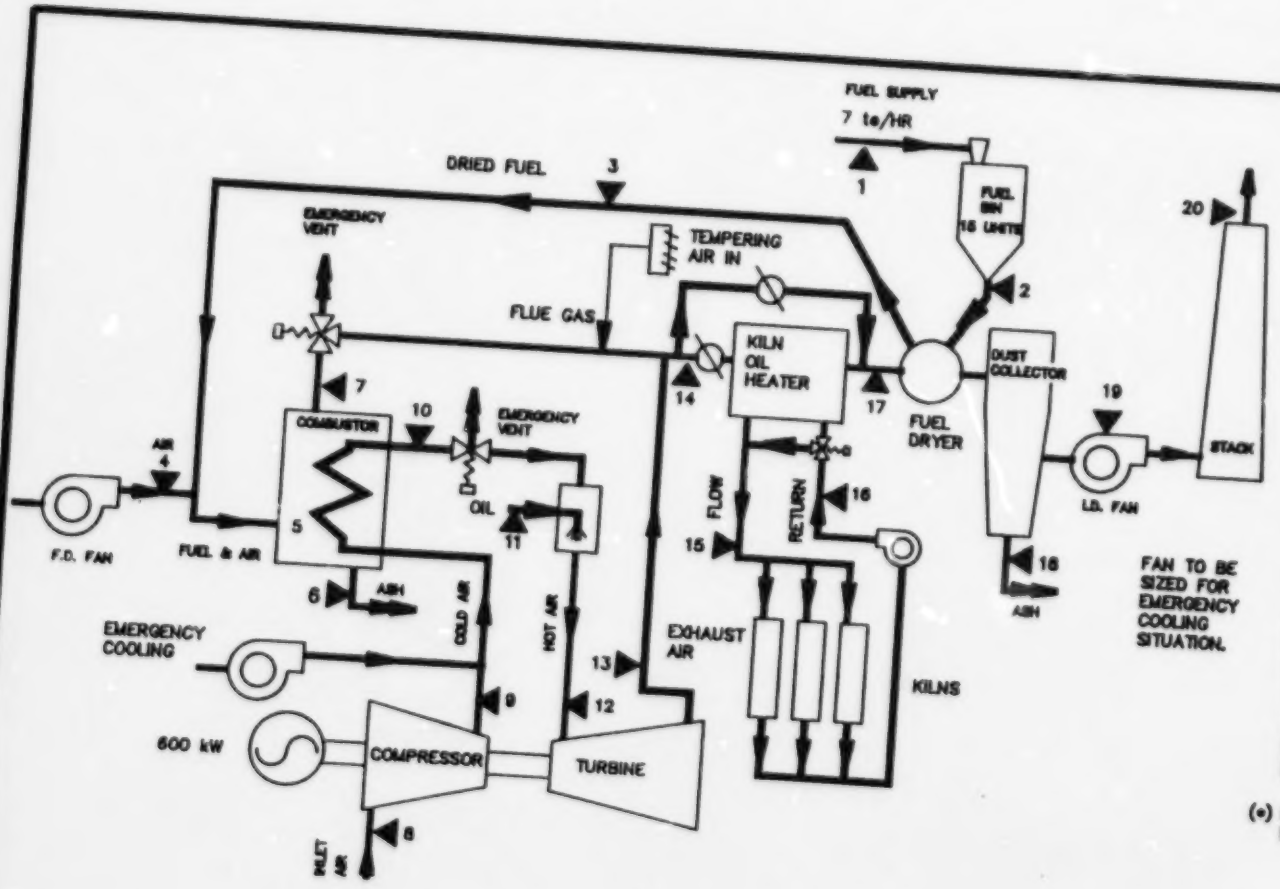

FLOW DATA

PT.	ENERGY FLOW (*)		MASS FLOW		TEMPERATURE		PRESSURE	
	BMTU/HR	MW	LB/SEC	KG/SEC	°F	°C	LB/IN²	KPA
1			4.3	1.95	60	15.5	15	101
2			2.5	1.14	60	15.5	15	101
3			1.6	0.73	60	15.5	15	101
4			13.5	6.14	60	15.5	15	101
5	37.0	10.8	15.5	7.03	2450	1343	16	108
6			.016	.007	100			
7	24.5	7.2	15.5	7.03	1670	910	15	101
8			13.4	6.1	60	15.5	15	101
9	4.9	1.4	13.4	6.1	491	255	89	610
10	17.4	5.1	13.4	6.1	1400	760	85	585
11			START - UP ONLY					
12	17.4	5.1	13.4	6.1	1400	760	81	560
13	9.2	2.7	13.4	6.1	822	439	15	101
14	33.7	9.8	28.9	13.1	1241	672	15	101
15	107	31	110	50	450	232	25	166
16	83	24.3	110	50	350	177	25	166
17	9.7	2.8	28.9	13.1	448	231	13	88
18			0.16	.007	100	38	15	101
19			29.8	13.5	310	154	12	81
20			29.8	13.5	310	154	15	101

(*) NOTES:
Based on (enthalpy)h=0 @ 60 F

PRELIMINARY FLOW CHART FOR SAWMILL COGENERATION / SAWDUST FUEL

NO.	DATE	ISSUED FOR	DESCRIPTION	DESIGN	APP'D.	NO.	DATE	ISSUED FOR	DESCRIPTION	DESIGN	APP'D.
A	11.3.87	PHASE II REPORT	DATA REVISED	TEH&R.L.E.							

WOOD WASTE CO-GENERATION

R.L. EVANS & Associates Ltd.
309-611 BEACH AVENUE, VANCOUVER, B.C. V6Z 2B5

PRELIMINARY FLOW CHART FOR SAWMILL COGENERATION/SAWDUST FUEL

OPTION 2

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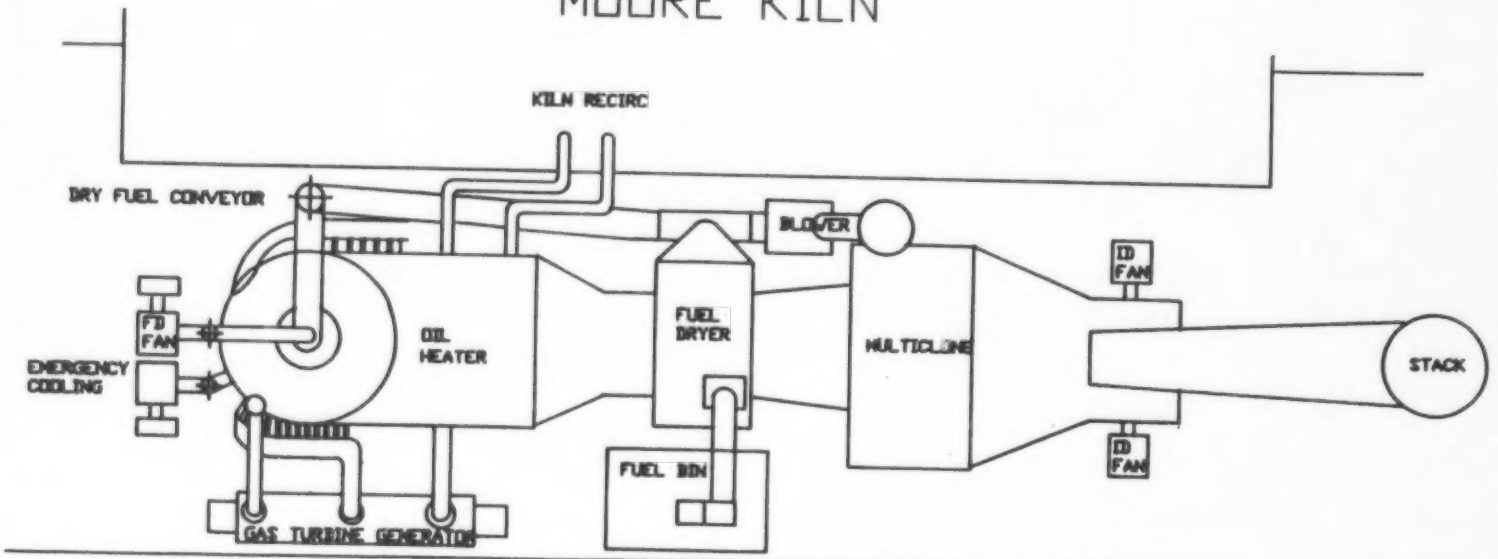
MOORE KILN



ROADWAY

NO.	DATE	ISSUED FOR	DESCRIPTION	DESIGN	APP'D.	NO.	DATE	ISSUED FOR	DESCRIPTION	DESIGN	APP'D.

WOOD WASTE CO-GENERATION

R.L. EVANS & Associates Ltd.
309-811 BEACH AVENUE, VANCOUVER, B.C. V6Z 2E5

SAWMILL COGENERATION PLANT PLAN

OPTION 2

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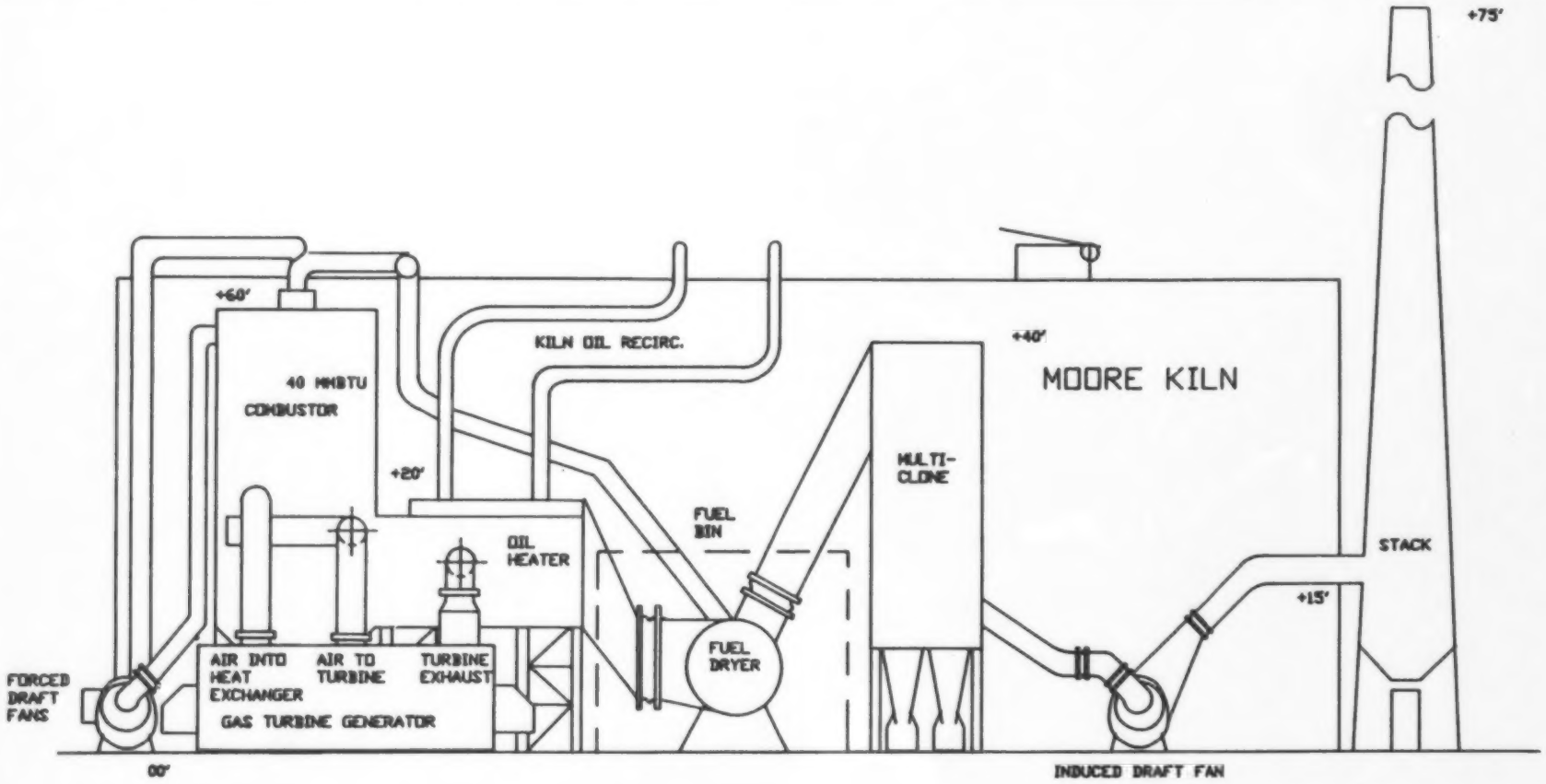


SAWMILL COGENERATION PLANT ELEVATION

NO.	DATE	ISSUED FOR	DESCRIPTION	DESIGN	APP'D.	NO.	DATE	ISSUED FOR	DESCRIPTION	DESIGN	APP'D.

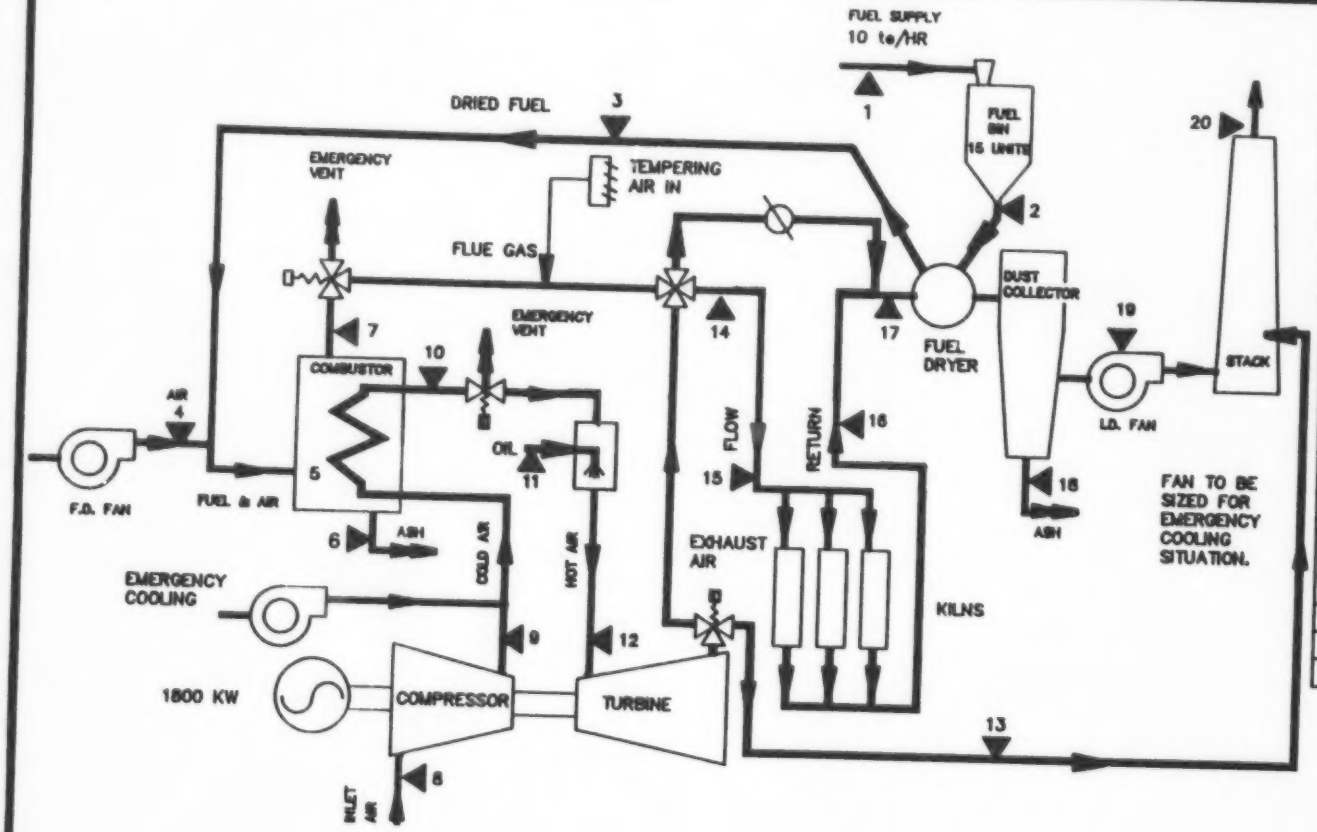
WOOD WASTE CO-GENERATION

R.L. EVANS & Associates Ltd.
309-811 BEACH AVENUE, VANCOUVER, B.C. V6Z 2E9

SAWMILL COGENERATION PLANT ELEVATION

OPTION 2

SCALE: NOT TO SCALE | DWG.NO. 87-50-007 | 9B



FLOW DATA

PT.	ENERGY FLOW BTU/HR	ENERGY FLOW MW	MASS FLOW LB/SEC	MASS FLOW KG/SEC	TEMPERATURE °F	TEMPERATURE °C	PRESSURE LB/IN²	PRESSURE KPA
1			4.3	1.95	60	15.5	15	101
2			3.1	1.4	60	15.5	15	101
3			2.0	0.9	60	15.5	15	101
4			19.3	8.75	60	15.5	15	101
5	55	16.1	21.3	9.66	2500	1371	16	108
6			.016	.007	100	38	15	101
7	21.25	6.2	21.3	9.66	1050	565	15	101
8			37.9	17.2	60	15.5	15	101
9	18.4	5.4	37.9	17.2	600	315	105	707
10	52.3	15.3	37.9	17.2	1400	760	103	693
11			START - UP ONLY					
12	52.3	15.3	37.9	17.2	1400	760	102	687
13			BY-PASS ONLY					
14	45.2	13.2	59.3	26.9	788	420	15	101
15								
16								
17	21.15	6.2	59.25	26.9	350	177	13	87.5
18			.016	.007	100	38	15	101
19			59.25	26.9	260	127	12	81
20			59.25	26.9	260	127	15	101

(•) NOTE:
Based on (enthalpy) h=0 @ 80°F

PRELIMINARY FLOW CHART FOR SAWMILL COGENERATION / SAWDUST FUEL

NO.	DATE	ISSUED FOR	DESCRIPTION	DESIGN	APP'D.	NO.	DATE	ISSUED FOR	DESCRIPTION	DESIGN	APP'D.
A	11.2.87	PHASE II REPORT	DATA REVISED								

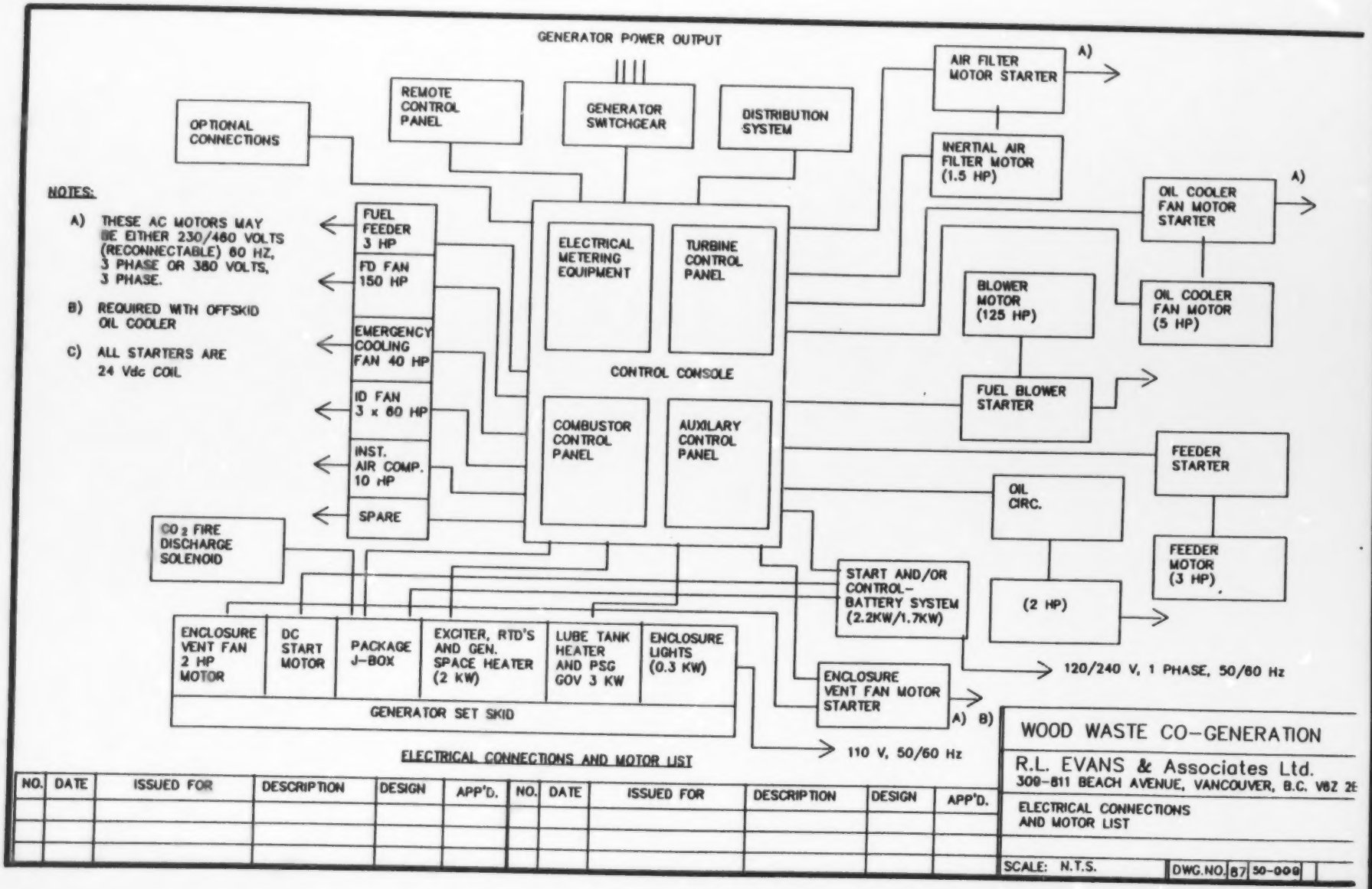
WOOD WASTE CO-GENERATION

R.L. EVANS & Associates Ltd.
300-811 BEACH AVENUE, VANCOUVER, B.C. V6Z 2E5

PRELIMINARY FLOW CHART FOR SAWMILL COGENERATION/SAWDUST FUEL

OPTION 3

SCALE: N.T.S. DWG NO. 87 50-00 S


GENERATOR POWER OUTPUT
OPTIONAL CONNECTIONS
REMOTE CONTROL PANEL
GENERATOR SWITCHGEAR
DISTRIBUTION SYSTEM
AIR FILTER MOTOR STARTER
A)
INERTIAL AIR FILTER MOTOR (1.5 HP)
OIL COOLER FAN MOTOR STARTER
A)
NOTES:
A) THESE AC MOTORS MAY BE EITHER 230/460 VOLTS (RECONNECTABLE) 60 HZ, 3 PHASE OR 380 VOLTS, 3 PHASE.
B) REQUIRED WITH OFFSKID OIL COOLER
C) ALL STARTERS ARE 24 Vdc COIL
FUEL FEEDER 3 HP
FD FAN 150 HP
EMERGENCY COOLING FAN 40 HP
ID FAN 3 x 60 HP
INST. AIR COMP. 10 HP
SPARE
ELECTRICAL METERING EQUIPMENT
TURBINE CONTROL PANEL
CONTROL CONSOLE
COMBUSTOR CONTROL PANEL
AUXILARY CONTROL PANEL
BLOWER MOTOR (125 HP)
OIL COOLER FAN MOTOR (5 HP)
FUEL BLOWER STARTER
FEEDER STARTER
OIL CIRC.
FEEDER MOTOR (3 HP)
(2 HP)
CO_2 FIRE DISCHARGE SOLENOID
START AND/OR CONTROL-BATTERY SYSTEM (2.2KW/1.7KW)
120/240 V, 1 PHASE, 50/60 Hz
ENCLOSURE VENT FAN 2 HP MOTOR
DC START MOTOR
PACKAGE J-BOX
EXCITER, RTD'S AND GEN. SPACE HEATER (2 KW)
LUBE TANK HEATER AND PSG GOV 3 KW
ENCLOSURE LIGHTS (0.3 KW)
GENERATOR SET SKID
ENCLOSURE VENT FAN MOTOR STARTER
A) B)
110 V, 50/60 Hz

ELECTRICAL CONNECTIONS AND MOTOR LIST

NO.	DATE	ISSUED FOR	DESCRIPTION	DESIGN	APP'D.	NO.	DATE	ISSUED FOR	DESCRIPTION	DESIGN	APP'D.

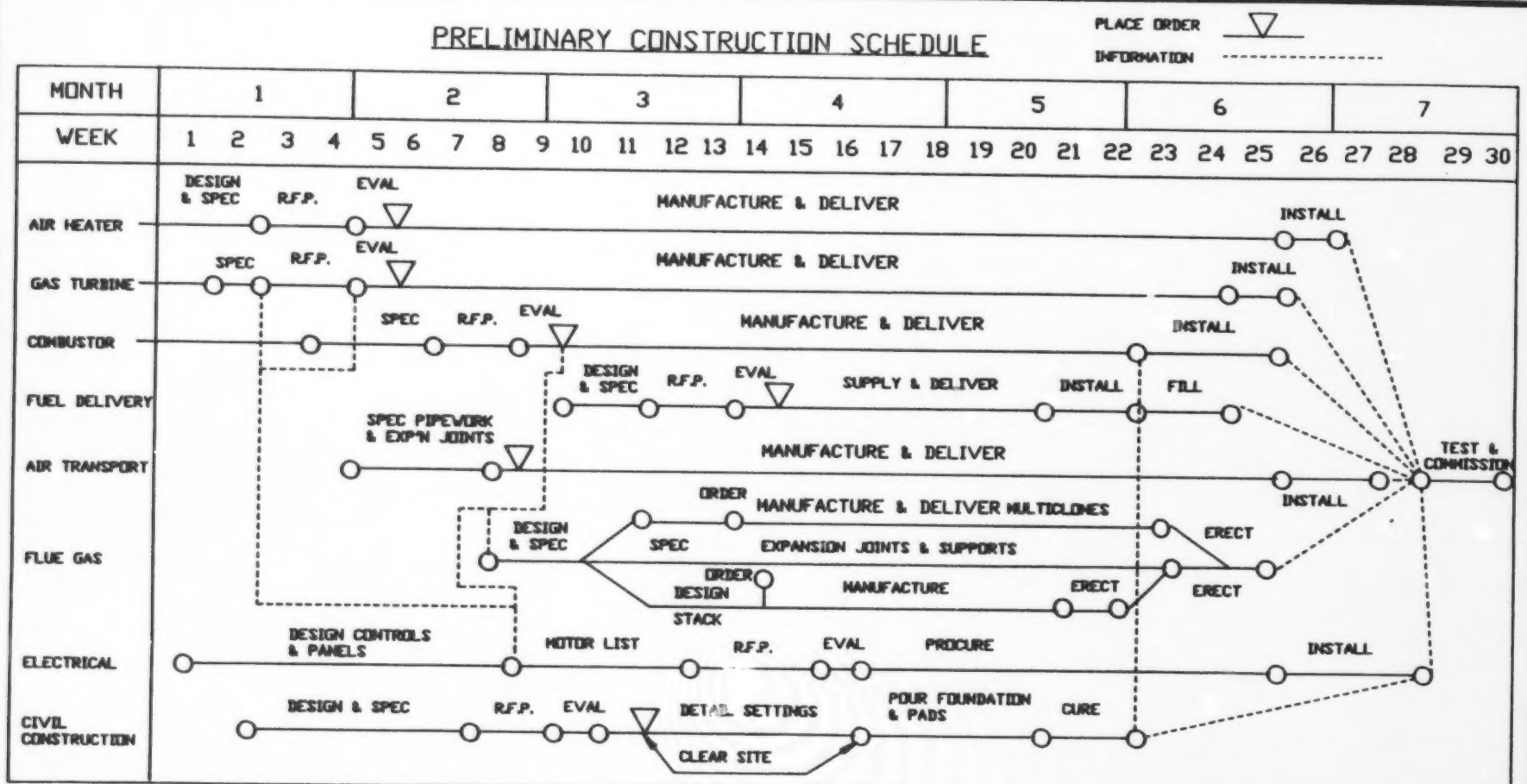
WOOD WASTE CO-GENERATION

R.L. EVANS & Associates Ltd.
309-811 BEACH AVENUE, VANCOUVER, B.C. V6Z 2E

ELECTRICAL CONNECTIONS AND MOTOR LIST

SCALE: N.T.S. DWG.NO. 87 50-009

PRELIMINARY CONSTRUCTION SCHEDULE



NO.	DATE	ISSUED FOR	DESCRIPTION	DESIGN	APP'D.	NO.	DATE	ISSUED FOR	DESCRIPTION	DESIGN	APP'D.

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WOOD WASTE CO-GENERATION

SCALE N.T.S. | DWG.NO. 87 50-010 | 48

APPENDIX C

CONTRACT DIRECTORY INFORMATION

APPENDIX C

CONTRACT DIRECTORY INFORMATION

TITLE: A WOOD-WASTE FUELLED INDIRECTLY-FIRED GAS TURBINE COGENERATION PLANT FOR SAWMILL APPLICATIONS. Phase II: Site-Specific Preliminary Engineering and Financial Analysis.

CONTRACTOR:

Canadian Resourcecon Ltd.
Suite 309-811 Beach Ave.
Vancouver, B.C.
V6Z 2B5

SCIENTIFIC AUTHORITY:

J.M. Charron
Renewable Energy Division
EMR Canada
460 O'Connor Street
Ottawa, Canada
K1A 0E4

PRINCIPAL INVESTIGATORS:

R.L. Evans (604)-228-6614
M.S. Sinclair (604)-682-8691

Contract
Serial No.: 23283-7-6038/01-SZ
DSS File No.: 51SZ 23283-7-6038

DURATION: June 1987 to March 1988

COST: $76,600

OBJECTIVE: To develop a cost-effective wood waste-fuelled, indirectly fired gas turbine cogeneration system to generate electricity and dry kiln heat for sawmills.

RESULTS: A preliminary engineering design and financial feasibility analysis were developed for the cogeneration system at a specific site. At the demonstration scale considered herein, the electrical generation component of the system is not economically viable without outside support, but a commercial scale unit shows very attractive rates of return under a variety of conditions.

CONCLUSION: Based upon the site-specific preliminary engineering design and financial feasibility analysis undertaken in Phase II of the project, it is concluded that the indirectly-fired cogeneration approach proposed in this project is technically and economically sound.

RECOMMENDATIONS:

The study team recommends that Phase III of the project be proceeded with in order to identify an appropriate demonstration site and to organize a demonstration project. The major objectives of Phase III are to: identify a short list of suitable sites and industrial participants; identify funding alternatives; evaluate a short list of sites; and structure a demonstration project.